A COMPARATIVE ANALYSIS OF STRESS CALCULATIONS FOR A TRANSVERSE BENT OF THE U. S. S. YORK TOWN

Norman O. Larson
Frank M. Perry, Jr.

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A COMPARATIVE ANALYSIS OF STRESS CALCULATIONS
FOR A
TRANSVERSE BENT OF THE U.S.S. YORKTOWN

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BY
LT. NORMAN O. LARSON, USN
LT. FRANK M. PERRY, JR., USN

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ABSTRACT

A Plexiglas model of Transverse Bent #155, U.S.S. YORKTOWN, was tested using the Beggs Deformeter. Test data from an experiment on the actual shipboard bent was available from a Taylor Model Basin report. This data was compared with the deformeter results and with the results derived from pure theory. The comparison indicated that the deformeter method and theory gave results essentially similar, differing by only an almost constant value. The stresses from the full-scale data differ from those calculated by the theory and by the deformeter method in a linear fashion and such differences give rise to a stress distribution factor relating the amount of load taken fore and aft by longitudinals along the transverse bent.

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INTRODUCTION

The analysis of structural problems by the use of models is not new, having been given its greatest impetus by Professor G. E. Beggs, of Princeton University, and his deformeter technique as early as 1922. Yet wide acceptance of this technique has not been the case for general structural analysis, the civil engineers being the only group using it widely in bridge construction.

Several ships' structures present possibilities for analysis by the deformeter method. Several of these are frames in longitudinally framed ships, transverse bents in aircraft carriers, and submarine ring frames.

The purpose of this thesis is to take some ships' structure that has had a full-scale stress analysis made on it, analyze it with a Beggs Deformeter and by theoretical means, and make a comparison of the accuracies and problems invloved in each method. These comparisons are made in the DISCUSSION OF RESULTS

CHOICE OF SUBJECT

The choice of a subject suitable for analysis by the Beggs Deformeter was limited by the relatively few comprehensive full-scale analyses recorde on ships' structure. The test conducted on the U.S.S. YORKTOWN by LCDR W.P. Roop, USN, and described in DTMB -.EMB Report #471, February 1941, "Strain Tests on Flight-Deck Framing of U.S.S. YORKTOWN and U.S.S. WASP", was chosen as the one most suitable for an analysis by the Beggs Deformeter.

Frame 155 of the U.S.S. YORKTOWN was the one chosen for test since results for two loads were recorded in the report, thus making for a more complete analysis. The loads were at the centerline

and the port quarter-point, as shown in Figure 1. Location of the gage stations are also indicated in this figure. The number indicates the order from the deck upward and inboard, the letter following denotes port or starboard, and the third symbol denotes inboard ar outboard.

Symbols beginning with D indicate stations for horizontal transverse deflections and symbols ending with D denote stations for vertical deflections. The preceding symbol indicates centerline, port, or starboard.

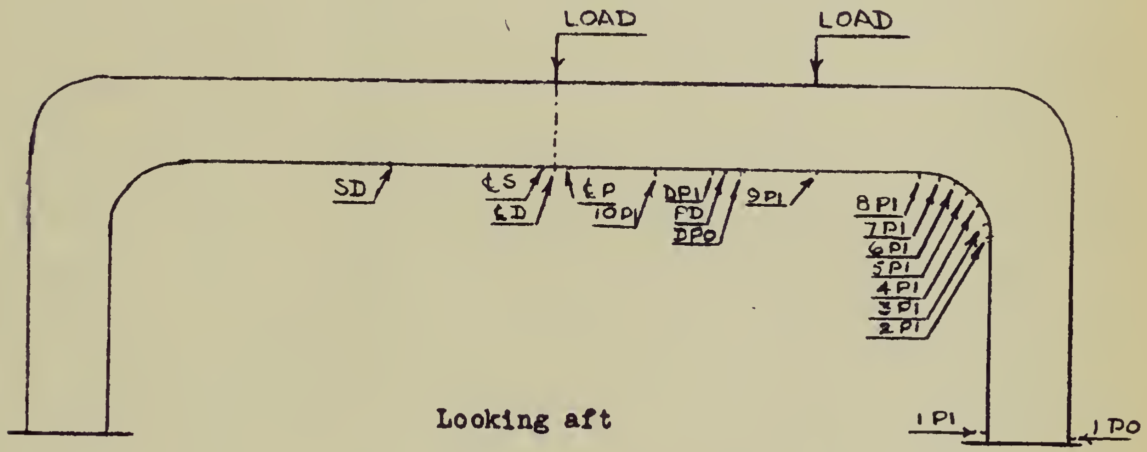

Figure 1 - Schematic outline of Bent at Frame 155

Location of Observing Stations

DEFORMETER THEORY AND MODEL SIMILITUDE.

A detailed development of the Deformeter Theory and Model Similitude is given in Appendix I. The deformeter method entails building a model, determining a series of influence numbers or lines from the ratios of interjected and measured deflections (deformations), and applying these influence numbers to the actual loads for the calculation of forces and stresses in the actual structure. Such a method is simple, relatively quick, and tends to remove causes for error in the analysis.

PREPARING THE DEFORMETER FOR TEST

1. The first step for preparing the deformeter for test was to prepare a level, smooth surface upon which to rest the deformeter apparatus and the model. A $3\frac{1}{2}'$ x 7' table top was smoothly sanded and varnished.

2. Calibration of the deformeter was the second step in this preliminary stage. A plastic specimen was mounted as a fixed reaction beam in a gage and the microscope successively zeroed on the centerline of a target 5.101" from the center of rotation of the specimen. Figure 2 shows this arrangement of gage and specimen. The various gage plugs were inserted in the gage and microscope readings taken for each gage plug insertion. These readings are recorded in Appendix II. The average readings are taken and the differences between the thrust and shear readings and their respective reversals constitute the thrust and shear microscope constants. They are actually the movement of the gage due to the insertion of the plugs expressed in microscope units. The difference between the moment readings and the reversed moment readings, however, must be divided by the target length, expressed in inches of prototype length which in this case is 5.101 x 24 inches. These constants are listed for their respective microscopes in Table I.

Microscope Constants			
Microscope	107AL	108AL	109AL
Thrust Constant	1296.7	1288.5	1287.6
Shear Constant	1283.2	1289.0	1293.6
Moment Constant	10.759	10.829	10.858

Table I

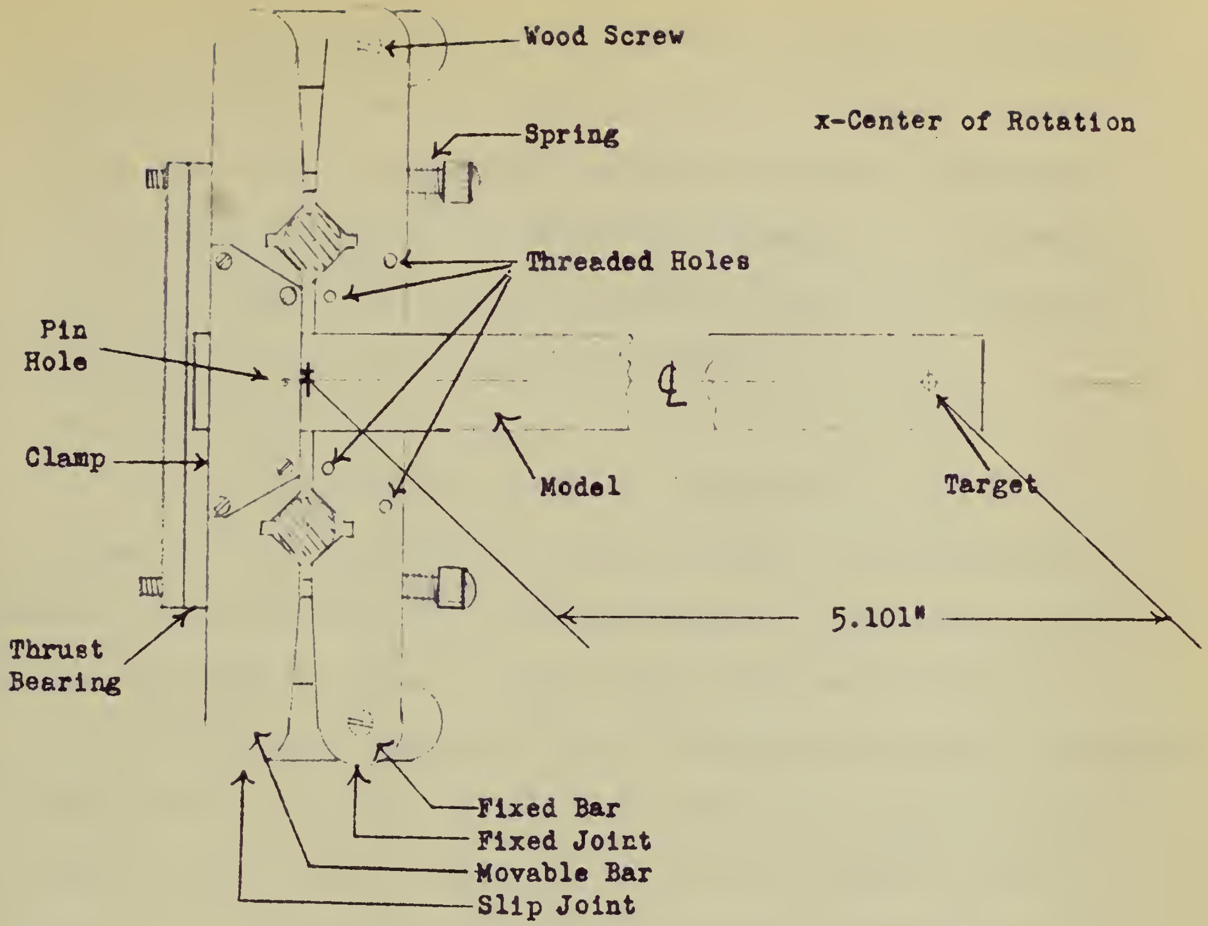

Figure 2- Specimen Mounted in Gage as a Fixed Reaction

3. The third phase in the preparation of the deformeter for test were the test runs conducted on an elementary beam, the shear, thrust, and moment of which could be easily calculated from theory. The results were accurate to within a few percent of the theoretical values. From these tests procedures were developed to be followed in the subsequent testing of the model of the bent.

CONSTRUCTING THE MODEL

A general description of the flight deck structure is as follows: "The flight deck is made up of a series of sections placed end to end and separated by transverse expansion joints. Each section normally stands by itself, on rigid transverse frames called bents, without support from adjoining sections except for transverse horizontal reactions at the expansions joints. ... three bents, spaced approximately 60 feet, support the section. Box girders beneath the deck edges, and a trussed girder along the centerline, extend over the length of the section and are supported by the bents. These longitudinal girders support intermediate transverse girders spaced at 16-foot intervals between bents. Resting on the transverse girders and on the bents are 12-inch longitudinal deck beams which support the deck plating to which the wood planking is attached."*

The cross sectional areas, moments of inertias, section moduli, and model cross sectional dimensions were determined from the plans of the bent (Refs. 30 and 31) at stations along the leg and span of the beam where the number, scantlings, or arrangement of effective members changed and in the neighborhood of the knees using sections as nearly equivalent as could be estimated. These

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* Reference 19, page 1

calculations are made and shown in Appendix III. The abscissa for this and all other graphs consists of a scale of distance from centerline measured along the lower flange of the prototype to the gage stations (target points) shown in Figure 1.

The plan of the model, Figure 3, gives dimensions of the model that are equivalent to the prototype. It also shows that the locations of the gage stations (target points) on the model are on the centerline, even though the actual gage stations were on the inner flange of the prototype. Since the axial force and bending moment are computed separately in the deformeter method the error introduced is negligible.

The model was constructed out of plastic to the dimensions shown on the plan. The model was cut on a bandsaw and filed to size by hand, using micrometers to get it to size. The magnitude of the error in finishing is shown by inspection of the plan. The characteristics of the plastic used are described in Appendix IV.

The target points indicated on the model plan were put on the model using horizontally and vertically scribed cross lines.

TESTING THE MODEL

1. Mounting the model. The feet of the bent model were mounted in gages, clamped to correspond to an assumed fixed end bent. Care was taken to insure that the centerlines of the gages and model coincided. This model was secured to the table using wood screws through the gages. The centerlines of the gages were placed parallel to each other and at the distance shown on the model plan. The perpendiculars to these centerlines at the feet of the model were made to be coincident when the normal plugs were inserted in the gages. The bases of the gages were separated from the table top with glass plates, and the

PLASTIC BENT MODEL

SCALE: FULL SIZE

LINEAR SCALE TO PROTOTYPE: 1"=24"

☐No. - ACTUAL WIDTH

⊙ - TARGET POINT

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PLASTIC BENT MODEL

SCALE: FULL SIZE
LINEAR SCALE TO PROTOTYPE: 1"=24"
No. - ACTUAL WIDTH
⊙ - TARGET POINT

LARSON-PERRY THESIS

model was supported at intervals along its length by ball bearings resting on similar glass plates. Lead weights were placed on the model over these ball bearings so that the model remained essentially in one plane.

2. Aligning the microscopes. Three microscopes were then aligned over the chosen targets. These targets were the same for all runs. Two placements of each microscope were necessary for each run as there were six targets. These targets were SD, ℄S, PD, 8PI, 4PI, and 2 PI. The procedure used for adjusting parallax and aligning the cross-hairs of the microscope was as recommended in Deformeter Bulletin #2 which was supplied with the equipment.

The horizontal and vertical crosshairs refer in each case to the scribed crosslines at the target points rather than to the model centerline and its normal.

The targets actually used in the succeeding tests were small specks of foreign material located as nearly as possible to the intersection of the scribed target lines on the model. As each plug was inserted in the given gage for each run, first the horizontal and then the vertical crosshair was brought over the target and successive microscope readings were taken. Four readings were taken and averaged for each plug and crosshair.

3. Run #1. Normal plugs were inserted in the starboard gage. Different plugs were inserted in the port gage and horizontal and vertical readings were taken at three microscope positions. The order of insertion of these plugs were normal, thrust, thrust reversed, shear, shear reversed, moment, and moment reversed. The microscopes were then shifted to the remaining target points and the plugs reinserted in the same order.

4. Run #2. Normal plugs were inserted in both gages. A floating gage was then placed in the model at 10PI. The centerline of the gage was placed coincident with the centerline of the model at 10PI. Normal plugs were inserted in this gage and the gage attached to the model by the small clamping bars. The normal plugs were removed and the model was severed between the clamping bars. The gage rested on two glass plates, with three ball bearings sandwiched between. The procedure for conducting the run was then identical to Run #1 except that the different plugs were inserted in this floating gage.

5. Runs #3, #4, #5. These runs were identical to Run #2 except that the floating gages were successively located at 9PI, 7PI, and SD. All previously cut sections had normal plugs inserted in their gages.

All readings taken for all runs are recorded in Appendix V.

Figure 4 shows the deformeter apparatus and setup for Run #5.

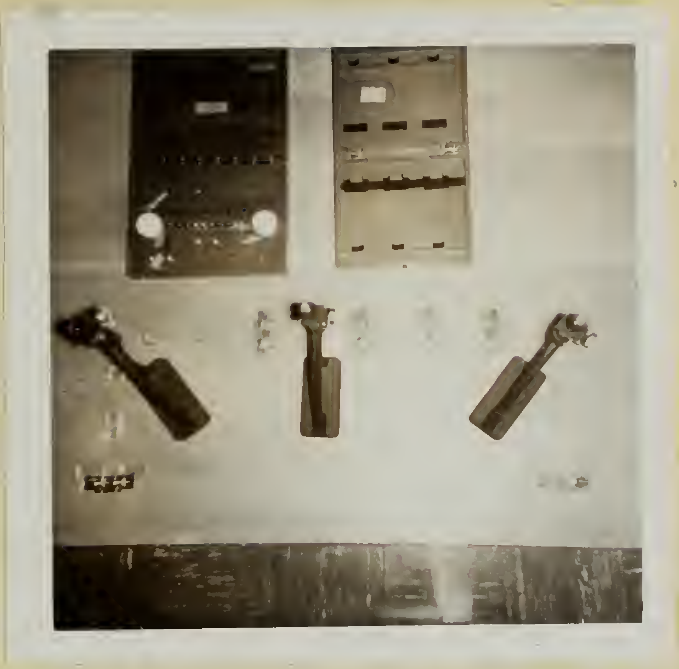

FIGURE 4a PLAN VIEW OF DEFORMETER SETUP

The plastic model is shown clamped in gages at the feet with floating gages mounted at four points on the span. The microscopes are set over targets on the plastic model. All gages have normal plugs in them so that the readings correspond to the uncut bent. Substitution of the thrust, shear, and moment plugs at any gage leads to the calculation of the influence coefficient at that gage position for a load at a microscope position. The gages are stored with the plugs in the box at the upper left in the picture. The box at the upper right normally holds the microscopes.

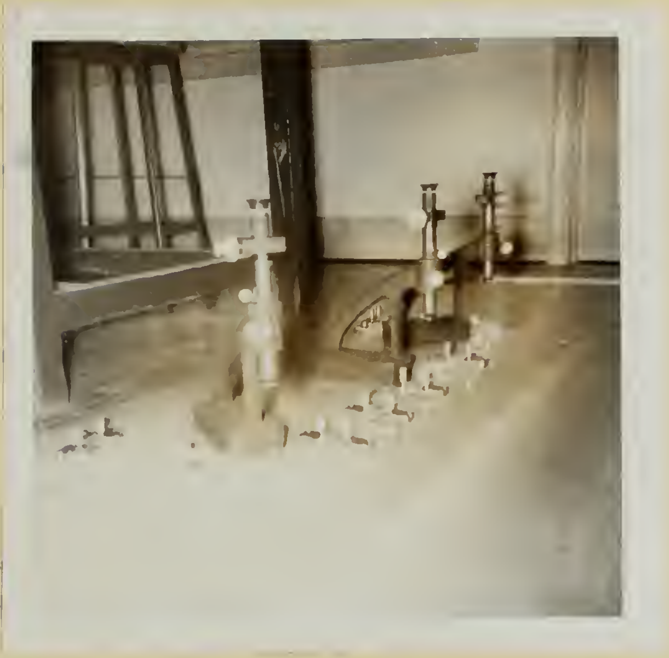

FIGURE 4b END VIEW OF THE DEFORMETER SETUP

The micrometer measuring head is seen near the eyepiece of the microscope. The knob on the head controls the movement of the cross-hairs in the field of vision of the microscope. Coarse readings of 100 units are made at the crosshairs on a scale in the field of vision, and the knob is graduated in 100 units per revolution for a fine reading. This reading can be interpolated by eye to 0.1 of a fine reading unit. Each unit is approximately equal to 0.001 millimeter.

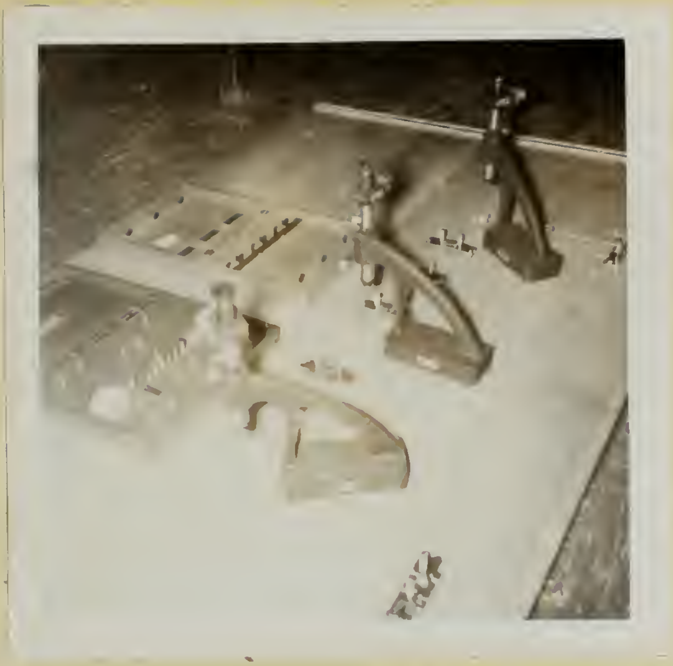

FIGURE 4c OBLIQUE VIEW OF THE DEFORMETER SETUP

Plugs are clearly shown in this view as are the glass plates on which the model rests. Lead weights on the bent model hold the model on the ball bearings so that it is in a plane at those points. These ball bearings rest on the glass plates. Floating gages also rest on glass plates, which in turn rest on other ball bearings, which are on the bottom plates.

REDUCING DEFORMETER DATA

All readings were averaged and the differences between averaged readings for plugs and the reversed positions were taken. Then these differences were divided by the microscope constants from Table I. For thrust and shear plugs, these give the ratio between the movement of the microscope targets to the motion of the gage -- and since both are in microscope units, the ratio is dimensionless. It is the y_x/y_Q value referred to in Appendix I. For the moment plugs the difference divided by the constant gives the moment at the gage point for a unit load at the target points.

These influence coefficients were plotted on their respective graphs in Appendix VI. From these points faired values of Axial Force, Shear, and Bending Moment were abtained. The slope of the bending moment curve was determined from an integration of the shear curve and this slope was used in obtaining the faired bending moment curve as well as the influence points from the microscope readings.

These faired curves were cross plotted to obtain the deformeter influence lines (solid lines) as shown in Figure 5.

THEORETICAL CALCULATIONS

The simplest bay portal frame that could be assumed was chosen to represent the transverse bent. The legs were assumed to have the same moment of inertia from the deck to the knee. The knee was assumed rigid. The beam was assumed to have a constant moment of inertia and different from the legs. These arbitrary values chosen were from Appendix III and are representative as average values of the actual effective moments of inertia of the bent.

MOMENTS OF INERTIA

LEG	66,631 in^4
BEAM	46,180 in^4

BENDING MOMENT PER UNIT LOAD IN 100 IN.LB./LB. AND SHEAR PER UNIT LOAD IN LB./LB
AXIAL FORCE PER UNIT LOAD IN LB./LB.
1.0
.9
.8
.7
.6
.5
.4
.3
.2
.1
0
-.1
-.2
-.3
-.4
-.5
-.6
-.7
-1.0
-.9
-.8
-.7
-.6
-.5
-.4
-.3
-.2
1
1'
2
2'
3
3'
4
4'
5
5'
7
7'
LEGEND
1) BENDING MOMENT AT SD
2) BENDING MOMENT AT 10 PI
3) BENDING MOMENT AT 9 PI
4) BENDING MOMENT AT 7 PI
5) SHEAR TO RIGHT OF LOAD
6) SHEAR TO LEFT OF LOAD
7) AXIAL FORCE
DEFORMETER VALUES SOLID
THEORETICAL VALUES DASHED

INFLUENCE LINES

DEFORMETER AND THEORETICAL VALUES

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BENDING MOMENT PER UNIT LOAD IN 100 IN.LB./LB. AND SHEAR PER UNIT LOAD IN LB./LB.
AXIAL FORCE PER UNIT LOAD IN LB./LB.
.6
.5
.4
.3
.2
.1
0
-.1
-.2
-.3
-.4
-.5
-.6
-.7
-.8
-.9
-1.0
-.8
-.7
-.6
-.5
-.4
-.3
-.2
-.1
.0
SD
CSC CP
10 PI
DPI
PD
DPO
9 PI
8 PI
7 PI
6 PI
5 PI
4 PI
3 PI
2 PI
1
1'
2
2'
3
3'
4
4'
5
5'
6
6'
7
7'
LEGEND
1) BENDING MOMENT AT SD
2) BENDING MOMENT AT 10 PI
3) BENDING MOMENT AT 9 PI
4) BENDING MOMENT AT 7 PI
5) SHEAR TO RIGHT OF LOAD
6) SHEAR TO LEFT OF LOAD
7) AXIAL FORCE
DEFORMETER VALUES SOLID
THEORETICAL VALUES DASHED

INFLUENCE LINES

DEFORMETER AND THEORETICAL VALUES

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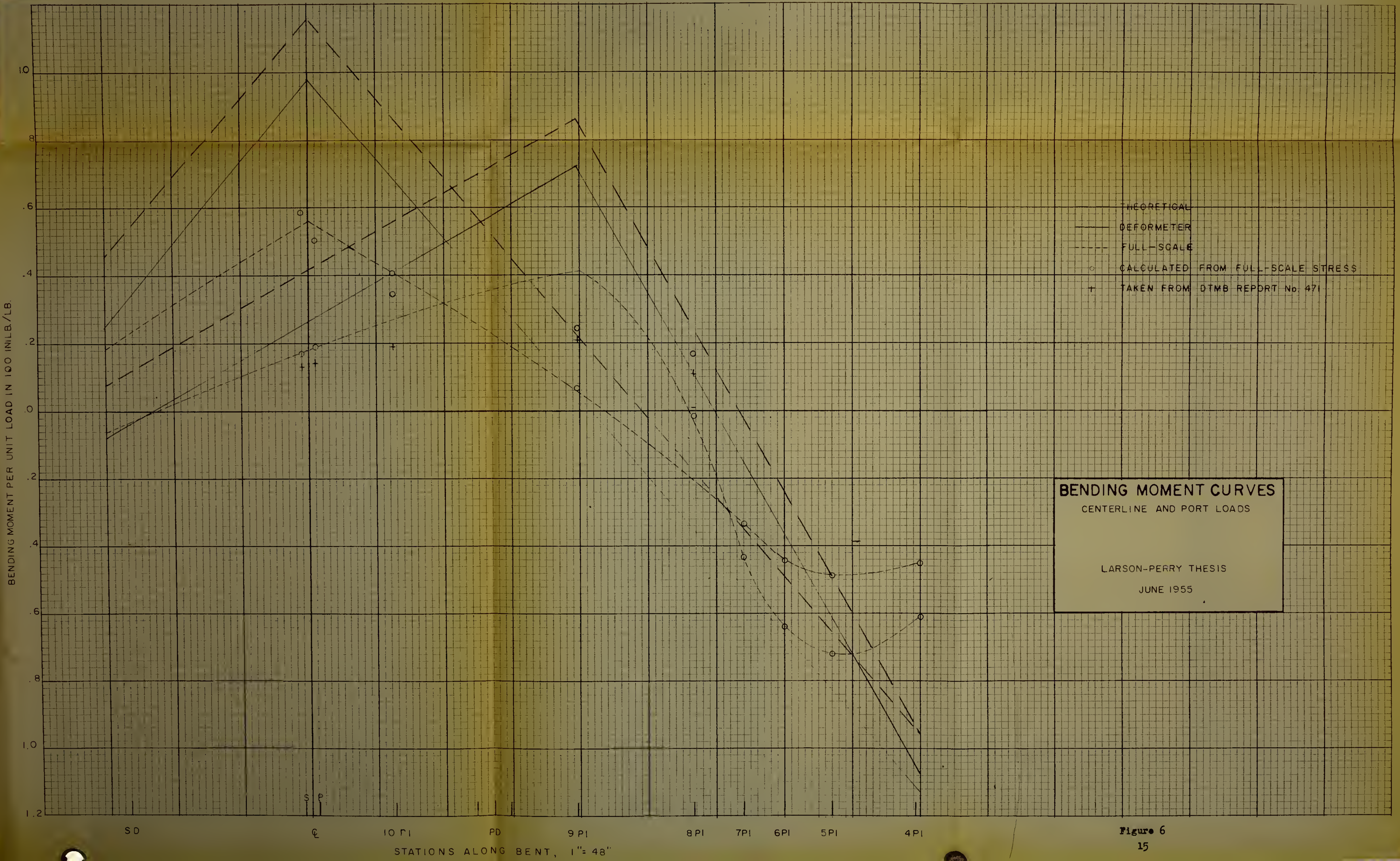
The formulas for determining the theoretical influence lines using these assumptions were taken from Reference 27 and the calculations are shown in Appendix VII.

These theoretical influence lines are plotted as the dashed lines in Figure 5.

A more rigorous mathematical treatment could have been used; however, it was not thought necessary to complicate the theory at this time because of the close agreement in the shape of the theoretical and deformeter influence line curves.

DERIVATION OF THE BENT DESIGN FORMULA

Theoretical and deformeter values from the influence lines curves and the stress values from the prototype Yorktown bent, abstracted from the DTMB-EMB report and tabulated in Appendix VIII, were used to determine the Bending Moment Curves and Total Stress Curves, figures 6, 7, and 8. The calculations that determine the stress curves for the theoretical and deformeter cases from their respective bending moment values and the calculations for determining the bending moment curves for the prototype case from the stress values are given in Appendix IX. Since theory and practical experience dictates that the maximum bending moment for a load occurs under the load, and since the points calculated from the full scale data of the prototype indicate that the maximum bending moment does not occur under the load, the value at 9PI was obviously in error for the port load. The value at 8PI for the centerline load does not fair in and it was assumed that the point was also in error, and was disregarded in the fairing. For the port load this point also does not fair in, and hence was again in error, but assuming this error to be constant, the point was taken into consideration to the extent of this error in fairing.



BENDING MOMENT CURVES
CENTERLINE AND PORT LOADS

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Figure 6

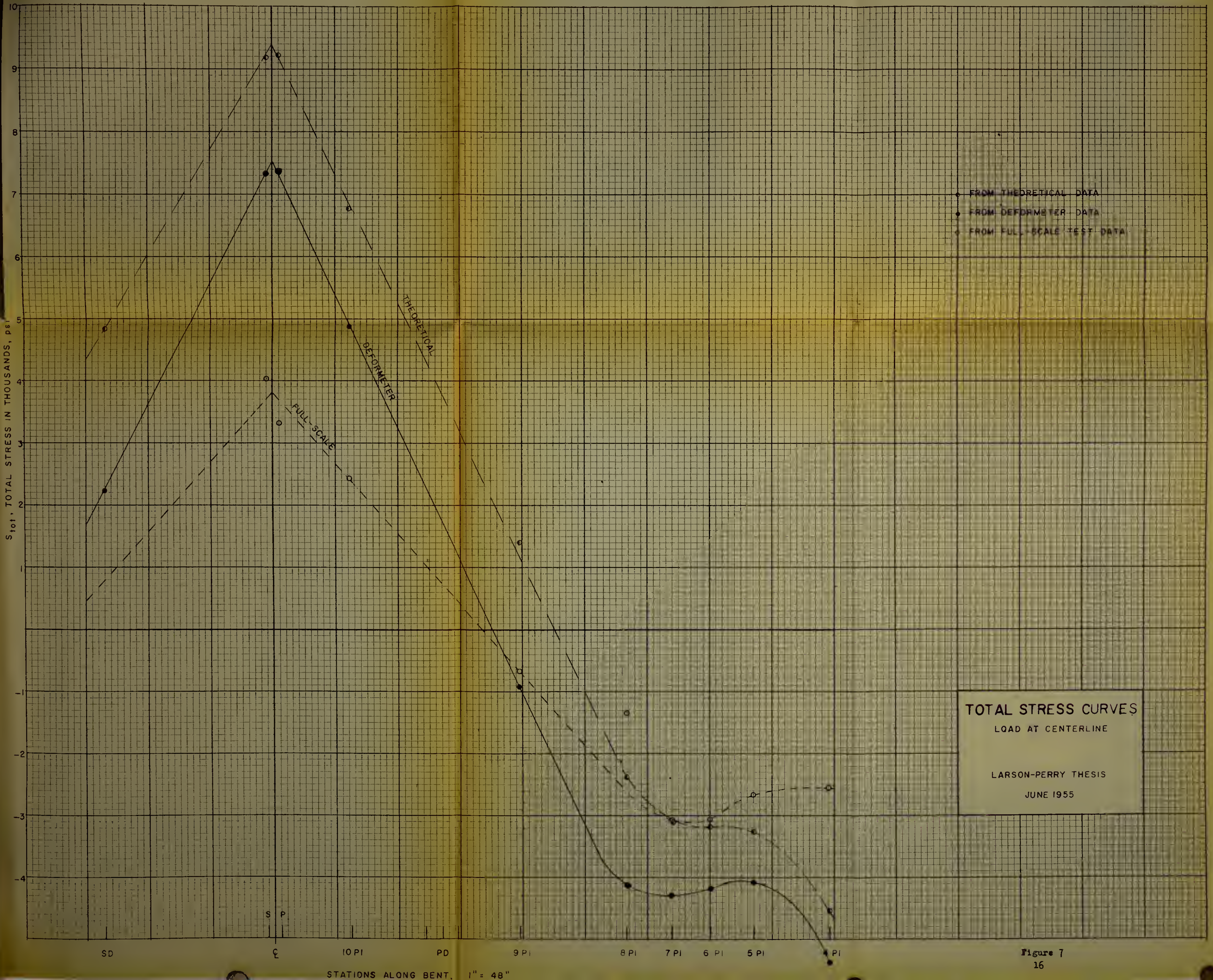
10
9
8
7
6
5
4
3
2
1
-1
-2
-3
-4
S_{tot}, TOTAL STRESS IN THOUSANDS, psi
THEORETICAL
DEFORMETER
FULL-SCALE
S P
SD
℄
10 PI
PD
9 PI
8 PI
7 PI
6 PI
5 PI
4 PI
STATIONS ALONG BENT, 1" = 48"
FROM THEORETICAL DATA
FROM DEFORMETER DATA
FROM FULL-SCALE TEST DATA
TOTAL STRESS CURVES
LOAD AT CENTERLINE
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Figure 7

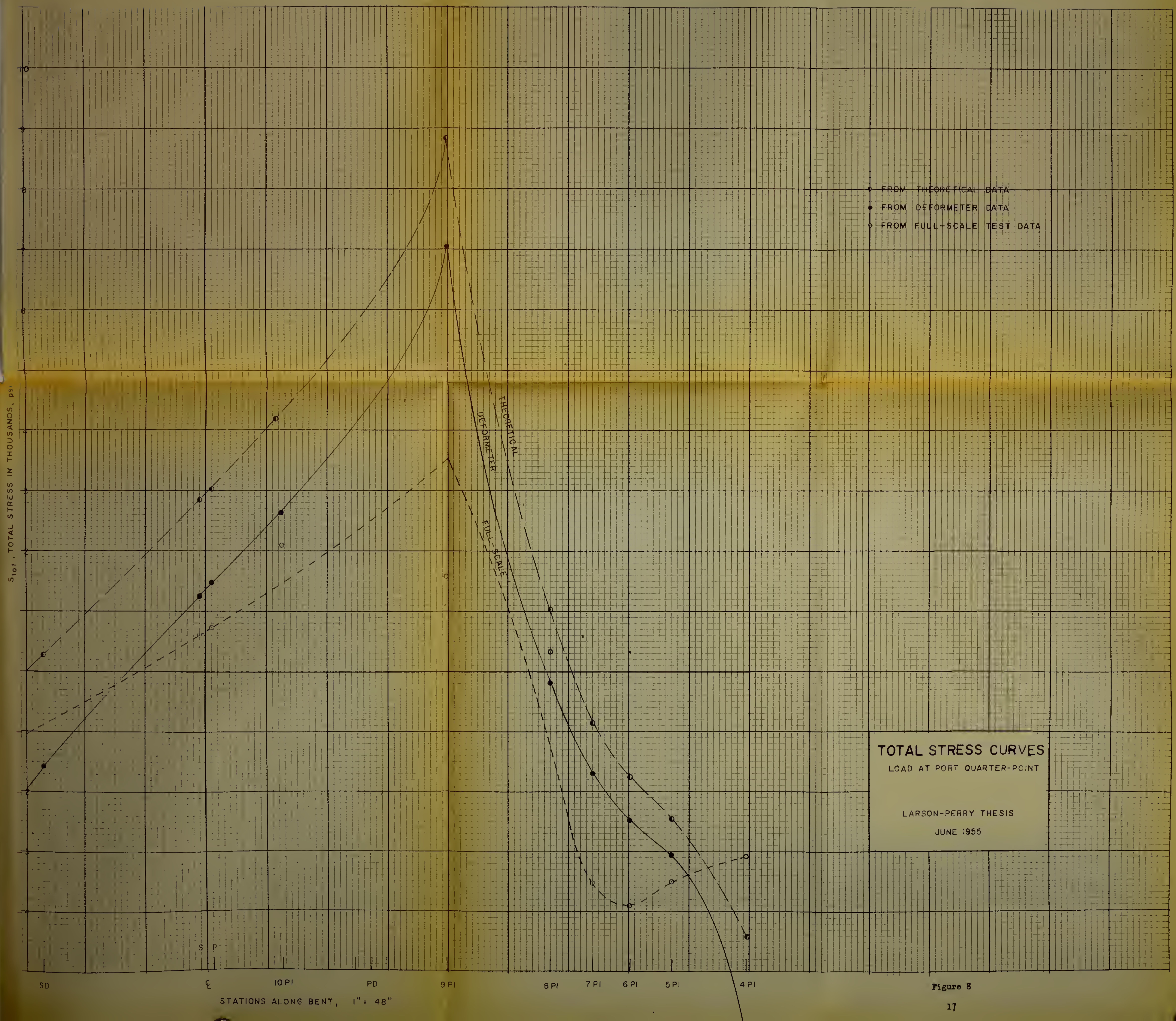
S$_{tot}$, TOTAL STRESS IN THOUSANDS, psi
10
9
8
6
4
3
2
FROM THEORETICAL DATA
FROM DEFORMETER DATA
FROM FULL-SCALE TEST DATA
THEORETICAL
DEFORMETER
FULL-SCALE
S P
SD
℄
10 PI
PD
9 PI
8 PI
7 PI
6 PI
5 PI
4 PI
STATIONS ALONG BENT, 1" = 48"
TOTAL STRESS CURVES
LOAD AT PORT QUARTER-POINT
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Figure 8

The maximum value of bending moment and stress for the port load was assumed to be at 9PI, the location of the load. The value of the bending moment at this point was taken to be the same percentage of the maximum deformeter value at the point as was the centerline load prototype to deformeter ratio. These curves were then faired in.

Difference curves, figures 9 and 10 were next obtained. These curves are plots of the stress differences between the theoretical and deformeter values, the theoretical and prototype values, and the deformeter and prototype values. The calculations for these points are tabulated in Appendix X. Curves were faired through these points and for the curves shown, mean stress difference lines were plotted as straight lines. These mean stress difference lines were used to determine the coefficients in the bent design formula.

The derivation of the bent design formula is given in Appendix XI. This formula is as follows:

$$S_x = S_{cl} K_1 - \frac{(x-a)}{(l-a)} (S_{cl} K_1 - S_{ce} K_2)$$

where: S_x = Stress in prototype bent girder lower flange in psi

S_{cl} = Calculated stress in bent girder under load in psi

S_{ce} = Calculated stress in bent girder at end of span in psi

x = Distance of stress point from ℄ in inches

a = Distance of load point from ℄ in inches

l = Distance of end of span from ℄ in inches

K_1, K_2 = Constants from figure 11

If S_{cl} and S_{ce} are calculated from theory K_{1T} and K_{2T} are used and if they are calculated from the deformeter method K_{1D} and K_{2D} are used.

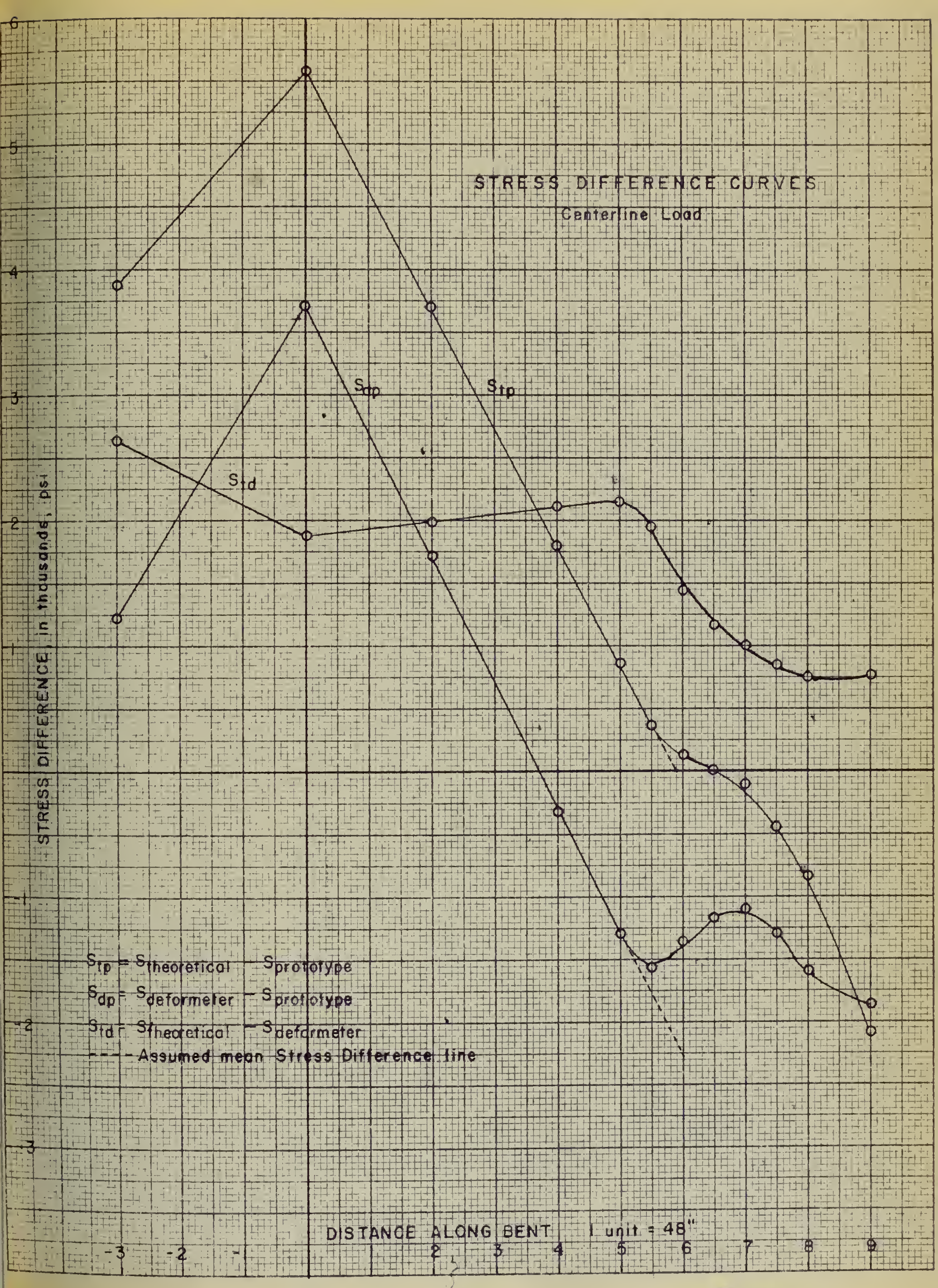

STRESS DIFFERENCE CURVES
Centerline Load
STRESS DIFFERENCE, in thousands, psi
DISTANCE ALONG BENT 1 unit = 48"
S_{dp}
S_{tp}
S_{td}
S_{tp} = $S_{theoretical}$ − $S_{prototype}$
S_{dp} = $S_{deformeter}$ − $S_{prototype}$
S_{td} = $S_{theoretical}$ − $S_{deformeter}$
---- Assumed mean Stress Difference line
6
5
4
3
2
1
-1
-2
-3
-3
-2
-
2
3
4
5
6
7
8
9
℄

Figure 9

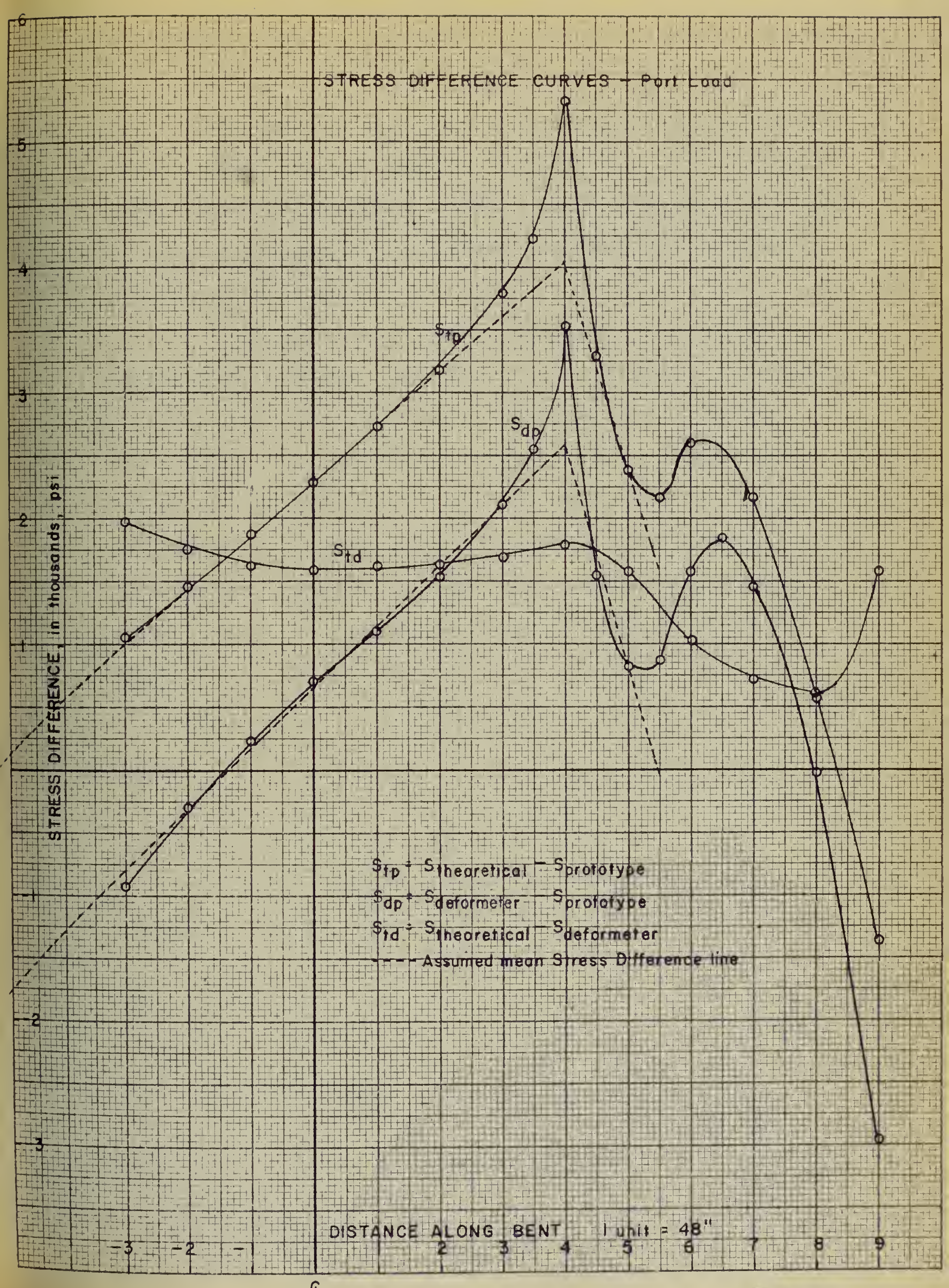

STRESS DIFFERENCE CURVES – Port Load
STRESS DIFFERENCE, in thousands, psi
DISTANCE ALONG BENT 1 unit = 48"
6
5
4
3
2
1
-1
-2
-3
-3
-2
-
1
2
3
4
5
6
7
8
9
℄
S_fp
S_dp
S_td
S_fp = S_theoretical − S_prototype
S_dp = S_deformeter − S_prototype
S_td = S_theoretical − S_deformeter
---- Assumed mean Stress Difference line

Figure 10

The limits of validity of this formula are indicated by the vertical dashed lines in figure 11. Since the mean stress difference curve deviated sharply from a straight line relationship at about 63% of the half bent span from centerline, this determined the limit of validity of the formula.

The location of the concentrated load from centerline is expressed by the abcissa of the curves as the percentage of the distance from centerline of the bent to centerline of the bent leg. The ordinate of the curves gives the values of K_1 and K_2 for theoretical and deformeter solutions at concentrated load points. Above the centerline are the values of the constants for determining stresses to port of the load point, and below the centerline are the values of the constants for determining stresses to starboard of the load point.

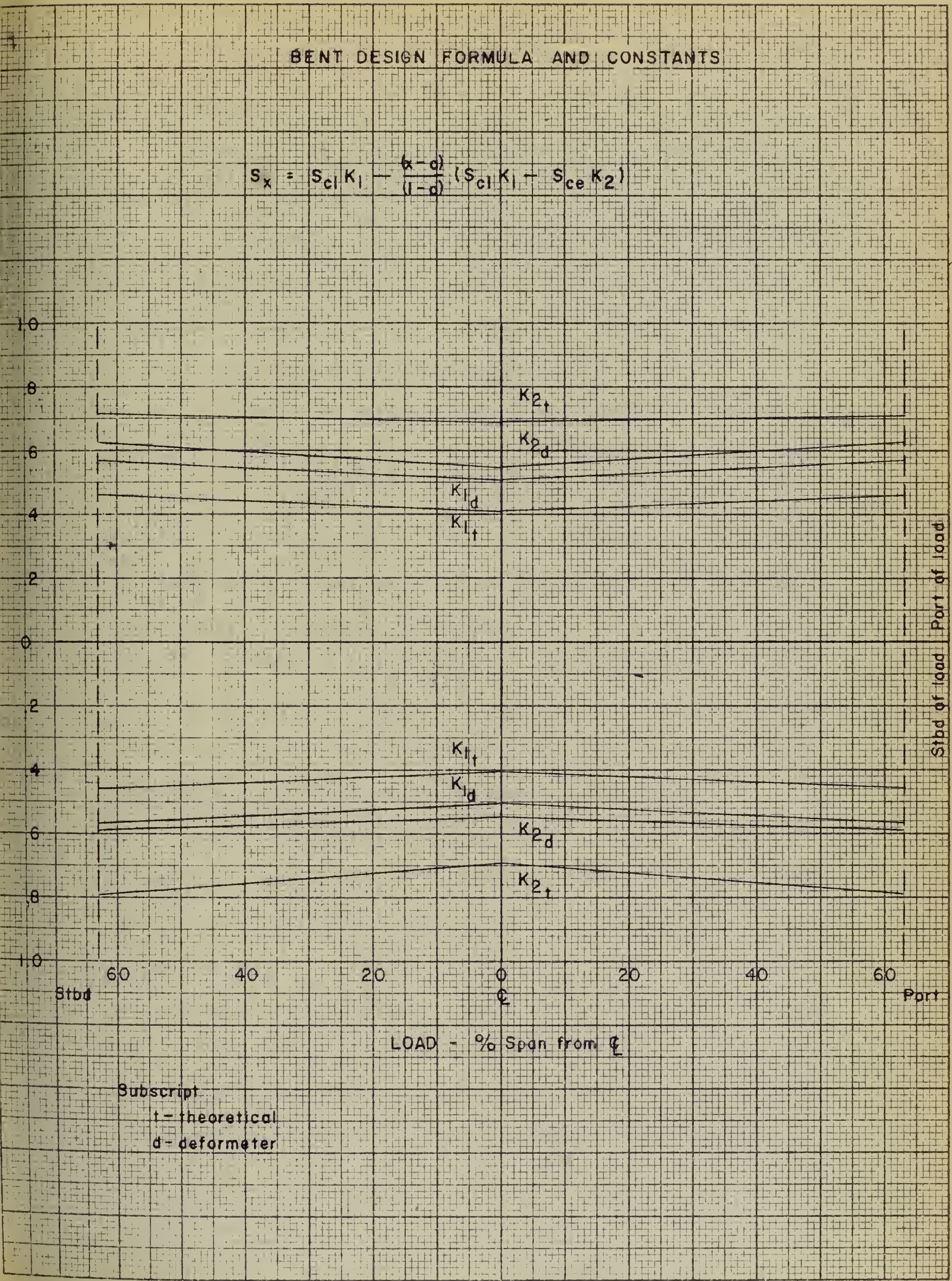

BENT DESIGN FORMULA AND CONSTANTS
$S_x = S_{cl} K_1 - \frac{(x-d)}{(l-d)} (S_{cl} K_1 - S_{ce} K_2)$
1.0
.8
.6
.4
.2
0
.2
.4
.6
.8
1.0
K_{2_t}
K_{2_d}
K_{1_d}
K_{1_t}
K_{1_t}
K_{1_d}
K_{2_d}
K_{2_t}
Stbd of load
Port of load
60
40
20
0
20
40
60
Stbd
℄
Port
LOAD - % Span from ℄
Subscript
t - theoretical
d - deformeter

Figure 11

DISCUSSION OF RESULTS

The major problems in the analysis of stresses in an aircraft carrier bent are as follows:

1. The determination of the proportion of the applied load carried by the transverse bent and the proportion carried by the longitudinal members to intermediate girders and other bents in the near vicinity of the bent under consideration.

2. Selection of the effective structural members in the vertical legs and horizontal girder for calculating the area, moment of inertia, and section modulus of the bent at each section. This becomes very difficult at the knee. The best method is to be found in reference 22, a modification of which was used in determining these values for the knee of this model.

3. Solution for stresses in a bent having these values of area, moment of inertia, and section modulus. Any rigorous solution based on the elastic theory is bound to involve a very complicated solution by means of relaxation or some similar method.

A comparatively simple method of analysis of stresses in a transverse bent of the USS Yorktown for concentrated loads on that bent has been developed in this thesis, which method will apply with reasonable accuracy to a bent on any carrier with a system of flight deck structure of similar construction, arrangement, and scantlings.

Knowing the load for which a bent is to be designed and the allowable stress in the lower flange of the bent, nominal areas and moments of inertia for the legs and girder are then assumed.

The values of S_{ce} and S_{cl} are computed by means of the theoretical method given in reference 27. When these assumed values give a solution for S_x that is essentially equal to the allowable value of S_x, then the values of area and moment of inertia thus determined may be used to design the sections of a bent. After the bent has been designed, it can be tested by means of the Beggs Deformeter, and the values of S_{cl} and S_{ce} again determined. Using these new values and the K_{1d} and K_{2d} values from figure 11, the deformeter S_x value can be determined by the formula. This S_x value should exist in the actual bent if constructed as designed and tested to these loads and should also agree with the value determined by the theoretical method.

The reason for the use of the Beggs Deformeter is evident from the curves of figure 11. The K_{1d} and K_{2d} values are very nearly the same for the deformeter solution. This indicates a high degree of comparison between the deformeter solution of stress in a two dimensional bent and the stress in its full-scale three dimensional prototype. The fact that K_1 and K_2 are not unity reveals the effect of the adjoining third dimensional structure since the deformeter model is a two dimensional representation of the full scale prototype standing alone. This means that the solutions are more nearly representative of what the stresses actually are in the bent than are the theoretical solutions.

In figures 10 and 11 it can be seen that within the limits of validity of the formula, the difference between the theoretical and deformeter values is practically a constant for the two loads. For the centerline load it is about 2000 psi and for the port load about 1700 psi. This shows that there is good correlation between

the theoretical and deformeter data. The deformeter model automatically corrects the solution for S_{ce} and S_{cl} for this difference, the order of magnitude of which might vary on other bents.

CONCLUSIONS

The Beggs Deformeter is a very useful tool in the solution of complicated ships' structures. Although it is not as rapid as a simply derived and applied theoretical formula, it is much faster than a very rigorous and accurate theoretical solution would be. By its very nature it tends to remove the inherent inaccuracies of simple theory applied to complicated structures.

From the deformeter solution and full-scale test data an empirical formula was derived which will give a representative picture of the distribution of stress. It is believed that this formula was derived in a logical manner and will give reasonable results for transverse bents of similar or normal construction under similar loading systems.

RECOMMENDATIONS

It is recommended that additional analyses of other bents or similar structures be made, using the method presented herein, in order to plot more points on the curves of constants in figure 11. This will greatly refine and improve them to such an extent that possibly a simple design criterion would result which would contain more fully substantiated constants.

BIBLIOGRAPHY AND REFERENCES

(1) Beggs, G. E., "An Accurate Mechanical Solution of Statically Indeterminate Structures by Use of Paper Models and Special Gages", Proceedings, American Concrete Institute, 18: pp 58 - 82. 1922.
See also Engineering and Contracting, May 24, 1922.

(2) Beggs, G. E., "Design of Elastic Structures from Paper Models", Proceedings, American Concrete Institute, 19: pp 53 - 66. 1923.

(3) Beggs, G. E., "Design of a Multiple Arch System" (Discussion of a paper by A. C. Janni), Transactions, A.S.C.E., 88: pp 1208-1230. 1925.

(4) Beggs, G. E., "The Use of Models in the Solution of Indeterminate Structures", Journal, Franklin Institute, 203: pp 375 - 386. 1927.

(5) Beggs, G. E., "Skew Arch Reactions Measured by Reciprocal Method", Engineering News - Record, 99: p 106. 1927.
See also Progress Report on Special Committee on Concrete and Reinforced Concrete, Proceedings, A.S.C.E., Society Affairs, p 169. 1927.

(6) Beggs, G. E., "A Discussion on Beggs Tester on the Arlington Memorial Bridge Arches", Engineering (London), 124: pp 31 - 35, pp 118 - 120. 1928

(7) Thomson, J. T., "Model Analysis of a Reinforced Concrete Arch", Public Roads (U.S. Department of Agriculture), vol. 9, no. 11.1. 1929.

(8) Beggs, G. E., "Deformeter Analysis for Rigid Frame Bridges of High Indeterminacy". In HAYDEN, The Rigid Frame Bridge (New York, Wiley), Chapt XII, pp 174 - 179. 1931.

(9) Thayer, E. S., In McCULLOUGH & THAYER, Elastic Arch Bridges, Chapt. VII. 1931.

(10) Moisseiff, L. S., "Designing the Tower of the Hudson River Bridge", Engineering News - Record, 100: p 819. 1928.

(11) Beggs, G. E., "The Beggs Deformeter", Engineering, 126: pp 31 - 35. July - December 1928.

(12) Glick, G. W., "Rigid Rectangular Frame Foundation for Albany Telephone Building", Engineering News - Record, 105: pp 836 - 838. 1930.

(13) McCullough, C. B., "Derivation of Theories Underlying Mechanical Methods of Stress Analysis", Ibid., 105: pp 489 - 490. 1930.

(14) Rathburn, J. C., "Simple Model Checks Indeterminate Structures", Civil Engineering (A.S.C.E.), 1: pp 131 - 132. 1930.

(15) Schaechterle, K., "Introduction to the Determination of Internal Stresses of Arbitrarily Loaded Statically Indeterminate Structure by Aid of Beggs Apparatus". (In German). Beton und Eisen, Heft 22, pp 406 - 410. 1930.

(16) LeRoy & Beaufoy, "Fundamental Difficulties of Deformeter Analysis", Engineering, 134: pp 671 - 673. July - December 1932.

(17) Timby, E. K., "Applied Mechanics and Model Analysis - Notes Concerning the Beggs Deformeter Apparatus", Princeton University. 1938.

(18) Maris, H. B. and Brock, J. S., "The Use of Plastic Models in Elastic Studies" (A Study of the Aircraft Carrier Bent Models), Naval Research Laboratory Report No. H - 1816. 27 November 1941.

(19) Roop, W. P., "Strain Tests on Flight Deck Framing of U.S.S. Yorktown and U.S.S. Wasp", DTMB Report No. 471. February 1941.

(20) Maugh, L. C., University of Michigan Progress Report #2 on Small Scale Tests of Ship Frame Corners (Results of Tests on Celluloid Models). Project No. M 342. November 1941.

(21) Osgood, W. R., "Stresses in a Rectanguler Knee of a Rigid Frame", Bureau of Standards Research Paper RP 1431. November 1941.

(22) Bleich, Dr. F., Memorandum to Director of Engineering, A.I.S.C. dtd 1 April 1942 regarding Two Schemes of Rigid Frame Knees.

(23) Maugh, L. C., Final Report on Small Scale Tests of Ship

Frame Corner (Results of Tests on Brass Models and Summary of All Tests. April 1942.

(24) Roop, W. P., "Tests of Rigid-Frame Models", Progress Report DTMB, July 1942.

(25) Eney, W. J., "A Large Displacement Deformeter Apparatus for Stress Analysis with Elastic Models", Society for Experimental Stress Analysis Proceedings, vol. VI, no. 2, pp 84 - 93. 1949.

(26) Charlton, T. M., "Model Analysis of Structures", E. & F. N. Spon, Ltd. 1951.

(27) Kleinlogel, A., "Rigid Frame Formulas", Ungar Publishing Co., New York. 1952.

(28) Rohm & Haas Co., "Technical Data, Plexiglas, Optical Properties", Fifth edition. 1952.

(29) Rohm & Haas Co., "Technical Data, Plexiglas, Mechanical Properties", Fourth edition. 1952.

(30) Bureau of C. & R. Plan No. 216298, CV5-6, Transverse Bent Under Flight Deck at Frame 155. 15 April 1937.

(31) Bureau of C. & R. Plan No. 216295, CV5-6, Flight Deck Plating Section 2 Between Frames 129 and 156. 4 May 1937.

(32) BuShips ltr S1/1(442) Ser 442-83 dtd 7 Oct 1954. (Information for Conducting a Thesis in Stress Analysis).

(33) DTMB ltr (720:EW:aes) dtd 14 October 1954. (Background Information for a Thesis in the Field of Stress Analysis).

(34) Beggs, G. E., Jr., "Deformeter Bulletin No. 2". (Supplied with equipment.)

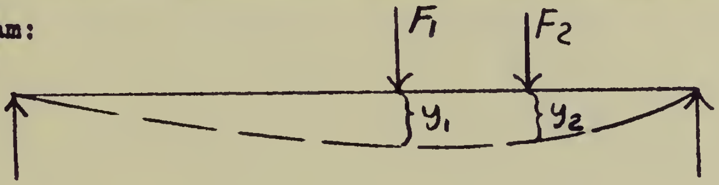
APPENDIX I

THEORY OF DEFORMETER AND MODEL SIMILITUDE

THEORY OF THE DEFORMETER METHOD

The Beggs Deformeter method is based on the Müller - Breslau principle and on the Maxwell - Betti reciprocal theorem. The latter theorem is applicable to linear structures and enables the former principle to be proved for indeterminate structures. Therefore proof of the suitability of the Beggs method will be simply derived from the latter.

Consider the following equations for the deflections of a simple beam:



$$y_1 = k_{11}F_1 + k_{12}F_2$$
$$y_2 = k_{21}F_1 + k_{22}F_2$$

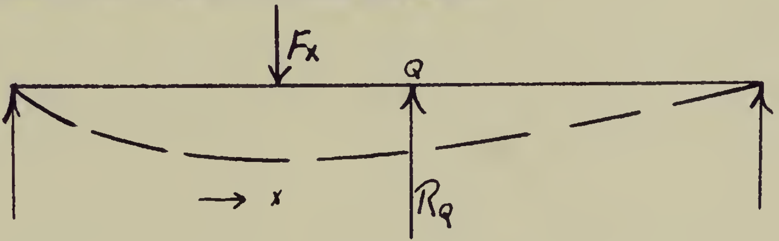
Where y and F are as noted on the figure and k_{nn} is a coefficient in standard use: the influence coefficient or flexibility coefficient.

In general, for n loads

$$y_n = k_{n1}F_1 + k_{n2}F_2 + \cdots + k_{nn}F_n$$

Maxwell and Betti proved that $k_{12} = k_{21}$, or, in general, $k_{ij} = k_{ji}$, $i = 1,2,3,\ldots$, $j = 1,2,3,\ldots$: and this relation is true for any kind of linear elastic structure.

Consider the following example:



If the support at Q is removed and a load F_x is applied at any point x then the deflection at Q caused by this load will be $F_x k_{Qx} = F_x K_{xQ}$. To nullify the deflection at Q an opposing force of R_Q must be applied such that $R_Q k_{QQ} = F_x k_{Qx}$, or

$$R_Q = F_x \cdot \frac{k_{Qx}}{k_{QQ}}$$

And, similarly, if a force F_Q is required to cause a deflection y_Q in the absence of the support, then

$$y_Q = k_{QQ} F_Q$$

and at any other point x on the structure

$$y_x = k_{xQ} F_Q$$

Then

$$\frac{y_x}{y_Q} = \frac{k_{xQ}}{k_{QQ}} \frac{F_Q}{F_Q} = \frac{k_{xQ}}{k_{QQ}} = \frac{k_{Qx}}{k_{QQ}}$$

Hence it follows that if the ratio of deflections y_x and y_Q can be determined then the ratio of k_{Qx} and k_{QQ} is known.

The deformeter method accomplishes this by (a) applying an arbitrary known deflection y_Q at the point of redundancy or where force values are required by the insertion into gages of closely machined plugs, (b) measuring the deflections y_x, at another point where a known or assumed force is acting, by a filar microscope, such measurement to be in the direction in which F_x is acting. Then , in the equation

$$R_Q = F_x \frac{k_{xQ}}{k_{QQ}} = F_x \frac{y_x}{y_Q}$$

R_Q may be computed and will be the component , of the total force acting at Q , that is acting in the direction in which y_Q was applied.

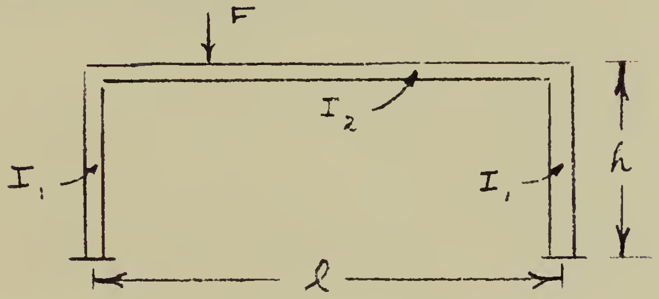
It remains then to convert R_Q , which is within the structure (in this case, the model) to the corresponding R_Q in another Structure

(the prototype) through the application of theories of model similitude.

MODEL SIMILITUDE

In developing the characteristics of the model to achieve model similitude with the structure, dimensional analysis by the Buckingham - theorem is used.

Consider a simple bay portal frame:



The deflection of the frame under action of the load F may be expressed as

$$y = \phi_1(h, l, I_1, I_2, E, F)$$

when deflection due to axial and shear forces is assumed negligible.

By the use of the Buckingham π- theorem and Van Driest's rule this may be expressed:

$$\psi_1(\pi_1, \pi_2, \pi_3, \pi_4) = 0$$

where

$$\pi_1 = l^{a_1} \cdot I_1^{b_1} \cdot E^{c_1} \cdot h$$

$$\pi_2 = l^{a_2} \cdot I_1^{b_2} \cdot E^{c_2} \cdot y$$

$$\pi_3 = l^{a_3} \cdot I_1^{b_3} \cdot E^{c_3} \cdot I_2$$

$$\pi_4 = l^{a_4} \cdot I_1^{b_4} \cdot E^{c_4} \cdot F$$

Substituting fundamental dimensions F and L for the variables:

$$\Pi_1 = L^{a_1} \cdot L^{4b_1} \cdot (FL^{-2})^{c_1} \cdot L = 0$$

$$\Pi_2 = L^{a_2} \cdot L^{4b_2} \cdot (FL^{-2})^{c_2} \cdot L = 0$$

$$\Pi_3 = L^{a_3} \cdot L^{4b_3} \cdot (FL^{-2})^{c_3} \cdot L^{4} = 0$$

$$\Pi_4 = L^{a_4} \cdot L^{4b_4} \cdot (FL^{-2})^{c_4} \cdot F = 0$$

where equating to zero indicates that the Π-values are dimensionless. Solving the equations for L :

$$a_1 + 4b_1 - 2c_1 + 1 = 0$$

$$a_2 + 4b_2 - 2c_2 + 1 = 0$$

$$a_3 + 4b_3 - 2c_3 + 4 = 0$$

$$a_4 + 4b_4 - 2c_4 = 0$$

for F :

$$c_1 = c_2 = c_3 = 0 , \quad c_4 - 1 = 0, \text{ or } c_4 = -1$$

Referring to the dimensional equations for Π it is seen that b_1, b_2, and a_3 are now superfluous since the equations may be satisfied by low integer values of the literal exponents remaining. Hence, setting the extraneous exponents equal to zero, we have

$$a_1 + 1 = 0 , \text{ or } a_1 = -1$$

$$a_2 + 1 = 0 , \text{ or } a_2 = -1$$

$$4b_3 + 4 = 0 , \text{ or } b_3 = -1$$

Substituting the value of c_4 in the last dimensional equation for Π :

$$a_4 + 4b_4 + 2 = 0$$

Choosing arbitrary values for a_4 and b_4 we find, for their lowest integer values:

$$a_4 = 2$$

$$b_4 = -1$$

Hence the values of π become:

$$\pi_1 = \frac{h}{l}, \ \pi_2 = \frac{y}{l}, \ \pi_3 = \frac{I_2}{I_1}, \ \pi_4 = \frac{Fl^2}{EI}$$

And the equation for deflection:

$$\psi_2\left(\frac{h}{l}, \frac{y}{l}, \frac{I_2}{I_1}, \frac{Fl^2}{EI} \right) = 0$$

or

$$y = l\phi_2\left(\frac{h}{l}, \frac{I_2}{I_1}, \frac{Fl^2}{EI} \right)$$

For flexural similarity of two portal frames the π -values of the deflection equation must be the same for both. Therefore the two frames must be geometrically similar as dictated by $\pi_1 = \frac{h}{l}$. The ratio of moments of inertia must be the same as dictated by $\pi_3 = \frac{I_2}{I_1}$. Equality of $\pi_2 = \frac{y}{L}$ and $\pi_4 = \frac{Fl^2}{EI}$ is used to correlate the loads and deflections of the frames. A further requirement for similarity is that both frames obey Hooke's Law under loading. If the effect of axial and shear forces are neglected (as they are in this development and in the model tests) the values of Poisson's ratio for the two frames need not be considered.

Choosing a model layout scale $\frac{1}{s}$ times as large as the prototype, and a model cross-section scale $\frac{1}{r}$ times those of the prototype, we have:

$$l = s\, l_m$$

and

(depth) $d = r\, d_m$

(thickness) $t = r\, t_m$ where m denotes the model.

Then

$$I = r^4 I_m$$

It follows that

$$\pi_3 = \frac{I_2}{I_1} = \frac{r^4 I_{2m}}{r^4 I_{1m}} = \frac{I_{2m}}{I_{1m}}$$

but

$$\pi_{3_m} = \frac{I_{2m}}{I_{1m}}$$

Therefore

$$\pi_{3_m} = \pi_3$$

Similarly:

$$\pi_1 = \frac{h}{l} = \frac{h}{s\, l_m}$$

but

$$\frac{h}{s} = h_m$$

and

$$\pi_1 = \frac{h_m}{l_m} = \pi_{1_m}$$

Again

$$\pi_2 = \frac{y}{l} = \frac{y}{s\, l_m}$$

$$\frac{y}{s} = y_m$$

$$\pi_2 = \frac{y_m}{l_m} = \pi_{2_m}$$

Finally

$$\pi_4 = \frac{Fl^2}{EI} = \frac{r^4 E\, F_m\, l^2}{s^2 E_m E\, r^4 I_m}$$

$$\frac{l}{s} = l_m$$

$$\pi_4 = \frac{F_m\, l_m^2}{E_m\, I_m} = \pi_{4_m}$$

From the above it has been shown that the π -values can be equilibrated for both model and prototype.

The general equation for deflection at any point P_1 on a structure due to a force F_R applied at any point R is:

$$y_P = F_R \frac{K_1 l^3}{EI}$$

where K is a constant taking into account layout arrangement, position of the load and its general distribution throughout the structure, and the action of the abutting members. Here again we neglect deflections due to axial, shear, and torsional forces.

Again employing the concept of influence or flexibility coefficients, k_{nn} :

$$k_{PR} = \frac{y_P}{F_R} = \frac{K_1 l^3}{E\,I}$$

where k_{PR} is the flexibility coefficient of the section at P.

For flexural similarity of two structures the flexibility coefficients describing deflection characteristics must be of the same ratio for both structures. Or, where m denotes the model:

$$\frac{k_{11}}{k_{11_m}} = \frac{k_{22}}{k_{22_m}} = \frac{k_{33}}{k_{33_m}} = \ldots = \frac{k_{PR}}{k_{PR_m}}$$

Then:

$$\frac{k_{PR}}{k_{PR_m}} = \frac{\frac{K_1 l^3}{E\,I}}{\left(\frac{K_1 l^3}{E\,I}\right)_m} = \frac{\frac{y_P}{F_R}}{\left(\frac{y_P}{F_R}\right)_m}$$

Let $K_1 = K_{1_m}$, indicating that the general arrangement and loading of the prototype and model are the same.

Dropping subscripts P and R :

$$\frac{y_m}{F_m} \frac{l^3}{E\,I} = \frac{y}{F} \frac{l_m^3}{E_m I_m}$$

But due to the π_2 - values being the same for model and prototype:

$$\frac{y}{l} = \frac{y_m}{l_m} \quad \text{, or} \qquad y = \frac{y_m\, l}{l_m}$$

Substituting:

$$\frac{y_m}{F_m}\,\frac{l^3}{E\,I} = \frac{y_m\,l\,l_m^2}{F\,E_m\,I_m}$$

or

$$F = \left(\frac{l_m}{l}\right)^2 \frac{E\,I}{E_m I_m} \cdot F_m$$

Substituting $I = r^4\,I_m$ and $l = s\,l_m$ into this force equation:

$$F = \frac{r^4\,E}{s^2\,E_m} \cdot F_m$$

With $k = \frac{y}{F}$ and $k_m = \frac{y_m}{F_m}$:

$$\frac{k}{k_m} = \frac{\dfrac{y\,s^2\,E_m}{r^4\,E\,F_m}}{\dfrac{Y_m}{F_m}}$$

And since $y = s\,y_m$

$$\frac{k}{k_m} = \frac{s^3 E_m}{r^4\,E}$$

Hence, for homogeneous materials and for the use of the same scale factors throughout, this ratio reduces to a constant for all similar points on both the prototype and the model.

Thus it is shown that the flexural similarity requirements may be met (that is, model and prototype π-values equal and the ratio of flexibility coefficients constant for similar points) by use of a homogeneous model with a layout scale of $\frac{1}{s}$ and a cross-section scale of $\frac{1}{r}$.

Since the model is cut from a sheet of constant thickness t_m its cross-section will be rectangular and its moment of inertia will be:

$$I_m = \frac{t_m\,d_m^3}{12}$$

And the depth or width of the member at the cross-section will be:

$$d_m = \sqrt[3]{\frac{12\,I_m}{t_m}}$$

but

$$I_m = \frac{I}{r^4}$$

Hence

$$d_m = \sqrt[3]{\frac{12\ I}{r^4 t_m}}$$

With a constant thickness t_m and a constant cross-sectional scale r this reduces to:

$$d_m = C\sqrt[3]{I}$$

for points on the model corresponding to similar points on the prototype. An arbitrary choice of values for C will then automatically determine a value for r and afterwards the value of r need not be considered in determining the dimensions of the model.

For this thesis a value of $C = .02$ was used, derived as follows:

Thayer indicates that the width of the member at the crown should be around 2% of the span of the model for good flexibility.

$$d_{midspan_m} = C\sqrt[3]{I_{midspan_p}}$$

From the dimensions of the U.S.S. YORKTOWN, frame 155:

$$l_p = 840" \text{ , and } I_p = 46{,}186 \text{ in}^4$$

$$\sqrt[3]{I_{midspan_p}} = 35.878$$

And

$$d_{midspan_m} = .02\ l_m$$

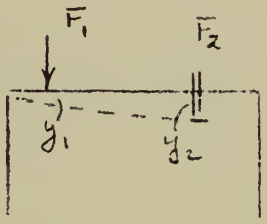
$$l_m = \frac{l_p}{s} = \frac{840}{24} \quad \text{using a scale factor } \tfrac{1}{2}" = 12" \text{ or } s = 24$$

Then

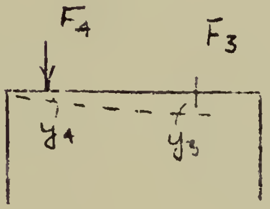
$$C = \frac{d_{midspan_m}}{\sqrt[3]{I_{midspan_p}}} = \frac{.02 \times 840}{24 \times 35.875} = .0195$$

Therefore we used $C = .02$ for simplification of our calculations.

It is quite simple to relate forces or moments derived from the model to those of the prototype.



Model



Prototype

Observe the following:

$$F_2 = \frac{F_1\, y_1}{y_2}\ , \text{ and } \quad F_4 = \frac{F_3\, y_3}{y_4}$$

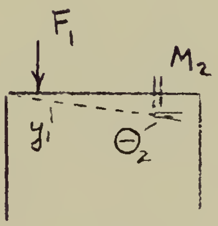
Choose $F_1 = F_4$ in magnitude, F_1 being the assumed force on the model and F_4 being the actual force on the prototype. Then

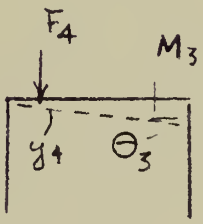
$$F_1 = F_4\ , \quad s\, y_1 = y_4\ , \quad s\, y_2 = y_3$$

Substituting

$$F_2 = F_4\, \frac{s\, y_4}{s\, y_3} = \frac{F_3\, y_3}{y_4} \cdot \frac{s\, y_4}{s\, y_3} = F_3 = \frac{F_1\, y_1}{y_2}$$

Similarly:





Model

Prototype

$$M_2 = \frac{F_1\, y_1}{\Theta_2}\ , \quad M_3 = \frac{F_4\, y_4}{\Theta_3}\ , \text{ or } \quad F_4 = \frac{M_3\, \Theta_3}{y_4}$$

and

$$s\,y_1 = y_4 \,, \quad \Theta_2 = \Theta_3 \,, \quad F_1 = F_4$$

Substituting

$$M_2 = \frac{M_3\,\Theta_3\,y_1}{s\,y_1\,\Theta_2} = \frac{M_3}{s} \,, \text{ or } s\,M_2 = M_3$$

and then

$$M_3 = \frac{s\,F_1\,y_1}{\Theta_2}$$

Hence forces existing in the prototype may be derived from the model, if the assumed load on the model equals the actual load on the prototype, by multiplying the assumed force on the model by a ratio of displacements of the model. Similarly, moments existing in the prototype may be calculated by multiplying the assumed force by a ratio of displacements of the model and, further, by the layout scale factor between the model and the prototype.

APPENDIX II

CALIBRATION OF DEFORMETER

BEGGS DEFORMETER
DATA SHEET

RECORDER PERRY
OBSERVER LARSON

POINT # CALIBRATION
MICROSCOPE # 109AL

SHEET # 1
DATE

PLUG	HORIZONTAL	VERTICAL
NORMAL	2215.4	2655.6
#.32510	2213.5	2655.9
	2214.3	2655.5
	2214.4	2655.1
SUM	8857.6	10622.1
AVERAGE	2214.4	2655.5

PLUG	HORIZONTAL	VERTICAL	PLUG	HORIZONTAL	VERTICAL
THRUST	2241.8	2015.3	THRUST	2236.4	3302.5
	2239.5	2019.3	REVERSED	2236.5	3301.1
#,34300	2239.3	2014.0	#.30701	2240.4	3302.9
	2241.0	2011.9		2239.2	3304.5
SUM	8961.6	8060.5	SUM	8952.5	13211.0
AVERAGE	2240.4	2015.1	AVERAGE	2238.1 2240.4 − 2.3	3302.7 2015.1 1287.6
DIFFERENCE					
CONSTANT					
COEFFICIENT					
SHEAR	1589.5	2661.2	SHEAR	2883.4	2655.5
#,34302	1589.9	2661.2	REVERSED	2883.6	2657.9
+	1591.0	2661.2	#.34302 +	2883.3	2658.5
#.30702	1589.3		#.30702	2883.6	2658.8
SUM	6359.7	7983.6	SUM	11533.9	10630.7
AVERAGE	1589.9	2661.2	AVERAGE	2883.5 1589.9 1293.6	2657.7 2661.2 − 3.5
DIFFERENCE					
CONSTANT					
COEFFICIENT					
MOMENT	1579.0	2668.4	MOMENT	2906.5	2661.7
#.32232	1575.5	2667.4	REVERSED	2903.6	2661.3
+	1576.5	2665.8	#.32232 +	2909.5	2660.3
#.32773	1578.0	2666.3	#.32773	2906.5	2660.3
SUM	6309.0	10667.9	SUM	11626.1	10643.6
AVERAGE	1577.2	2667.0	AVERAGE	2906.5 1577.2 1329.3	2660.9 2667.0 − 6.1
DIFFERENCE					
CONSTANT					
COEFFICIENT					

MICROSCOPE ZERO = 1996.5

BEGGS DEFORMETER
DATA SHEET

RECORDER *PERRY*
OBSERVER *LARSON*

POINT # *CALIBRATION*
MICROSCOPE # *108AL*

SHEET # *2*
DATE

PLUG	HORIZONTAL	VERTICAL
NORMAL	2001.0	2290.3
#.32509	2001.5	2291.9
	2001.5	2292.3
	2001.3	2290.7
SUM	8005.3	91652
AVERAGE	2001.3	2291.3

PLUG	HORIZONTAL	VERTICAL	PLUG	HORIZONTAL	VERTICAL
THRUST	2006.1	1649.2	THRUST	1999.9	2938.3
#.34300	2004 9	1649.9	REVERSED	1997.5	2937.0
	2006.1	1648.6	#.30701	1998.5	2937.5
	2005.0	1647 9		1999.3	2936.7
SUM	8022.1	6595.6	SUM	7995.2	11749.5
AVERAGE	2005.5	1648.9	AVERAGE	1998.8	2937.4
DIFFERENCE				2005.5	1648.9
CONSTANT				– 6.7	1288.5
COEFFICIENT					
SHEAR	1359 9	2279.1	SHEAR	2648.6	2288.9
#.34302	1359.8	2277.2	REVERSED	2649.0	2287.3
+	1359 7	2277.9	#.34302 +	2648.3	2289.8
#.30702	1360.3	2279.3	#.30702	2649.6	2288.1
SUM	5439 7	9113.5	SUM	10555 5	9154.1
AVERAGE	1359.9	2278.4	AVERAGE	2648.9	2288.5
DIFFERENCE				1359.9	2278.4
CONSTANT				1289.0	+ 10.1
COEFFICIENT					
MOMENT	1341.1	2288.8	MOMENT	2666.1	2296.3
#.32232	1339.2	2288.5	REVERSED	2665.0	2296.0
+	1339.1	2289.0	#.32232 +	2665.6	2296.2
#.32773	1340.1	2289.2	#.32773	2666.1	2296.1
SUM	5359.5	9155.5	SUM	10662.8	9184.6
AVERAGE	1339.9	2288.9	AVERAGE	2665.7	2296.2
DIFFERENCE				1339.9	2288.9
CONSTANT				1325.8	+ 7.3
COEFFICIENT					

MICROSCOPE ZERO = 2008.0

BEGGS DEFORMETER
DATA SHEET

RECORDER Perry
OBSERVER Larson

POINT # CALIBRATION
MICROSCOPE # 107 AL

SHEET # 3
DATE

PLUG	HORIZONTAL	VERTICAL
NORMAL	1929.0	24398
#.32510	1931.5	2441.1
	1932.3	2439.9
	1928.4	2438.8
SUM	772,1 2	9759.6
AVERAGE	1930.3	2439.9

PLUG	HORIZONTAL	VERTICAL	PLUG	HORIZONTAL	VERTICAL
THRUST	1941.1	1793.2	THRUST	1935.1	3090.5
# .34300	1943.7	1793.2	REVERSED	1933.9	3089.9
	1945.1	1799.2	# 30701	1934.1	3090.1
	1946.6	1793.6		1934.8	3090.4
SUM	7776.5	71742	SUM	77379	12360.9
AVERAGE	1944.1	1793.5	AVERAGE	1934.5	3090.2
DIFFERENCE				1944.1	1793.5
CONSTANT				— 9.6	1296.7
COEFFICIENT					
SHEAR	1297.2	2433.1	SHEAR	2582.0	2436.2
#.34302	1296.2	2430.4	REVERSED	2582.5	2435.0
+	1300.0	2435.0	#.34302	2581.0	2436.3
# .30702	1299 4	2433.8	+	2580.3	2437.2
			#.30702		
SUM	5192.8	9732.3	SUM	10325.8	97447
AVERAGE	1298.2	2433.1	AVERAGE	2581.4	2436.2
DIFFERENCE				1298.2	2433.1
CONSTANT				1283.2	+ 3.1
COEFFICIENT					
MOMENT	1281.8	2445.3	MOMENT	2596.5	2439.3
# .32232	1279.1	2446.4	REVERSED	2597.7	24379
+	1281.1	2447.5	#.32232	2598.2	2438.4
# .32773	1279 4	2448.1	+	2598.1	2440.3
			# .32773		
SUM	5121.4	9787.3	SUM	10390.5	97559
AVERAGE	1280.4	2446.8	AVERAGE	2597.6	2439.0
DIFFERENCE				1280.4	2446.8
CONSTANT				1317.2	- 7.8
COEFFICIENT					

MICROSCOPE ZERO = 1986.1

MICROSCOPE 107AL

Thrust constant = 1296.7

$$\Delta T = .34300 - .30701 = .03599$$

$$1 \text{ mm.} = \frac{1296.7}{\sqrt{2} \times 25.4000 \times .03599} = \frac{1296.7}{1.2928} = 1003.0 \text{ units}$$

Shear constant = 1283.2

$$\Delta S = .34302 - .30702 = .03600$$

$$1 \text{ mm.} = \frac{1283.2}{\sqrt{2} \times 25.400 \times .03600} = \frac{1283.2}{1.2932} = 992.3 \text{ units}$$

$$\text{Moment constant} = \frac{1317.2}{5.101 \times 24} = \frac{1317.2}{122.424} = 10.759$$

$$\Delta M = .32773 - .32232 = .00541$$

$$1 \text{ mm.} = \frac{1317.2 \times 1.5}{\sqrt{2} \times 25.400 \times .00541 \times 5.101 \times 2} = \frac{1317.2}{1.3217} = 996.6 \text{ units}$$

Manufacturers' furnished calibration data 1 mm. = 999 units(±0.4%)

MICROSCOPE 108AL

Thrust constant = 1288.5

$$\Delta T = .343000 - .30701 = .03599$$

$$1 \text{ mm.} = \frac{1288.5}{\sqrt{2} \times 25.400 \times .03599} = \frac{1288.5}{1.2928} = 996.7 \text{ units}$$

Shear constant = 1289.0

$$\Delta S = .34302 - .30702 = .03600$$

$$1 \text{ mm.} = \frac{1289.0}{\sqrt{2} \times 25.400 \times .03600} = \frac{1289.0}{1.2932} = 996.8 \text{ units}$$

$$\text{Moment constant} = \frac{1325.8}{5.101 \times 24} = \frac{1325.8}{122.424} = 10.829$$

$$\Delta M = .32773 - .32232 = .00541$$

$$1 \text{ mm.} = \frac{1325.8 \times 1.5}{\sqrt{2} \times 25.400 \times .00541 \times 5.101 \times 2} = \frac{1325.8}{1.3217} = 1003.1 \text{ units}$$

Manufactureer's furnished calibration data 1 mm. = 1000 units(±4%)

MICROSCOPE 109AL

Thrust constant = 1287.6

$\triangle T = .34300 - .30701 = .03599$

$$1\text{ mm.} = \frac{1287.6}{\sqrt{2} \times 25.400 \times .03599} = \frac{1287.6}{1.2923} = 996.0\text{ units}$$

Shear constant = 1293.6

$\triangle S = .34302 - .30702 = .03600$

$$1\text{ mm.} = \frac{1293.6}{\sqrt{2} \times 25.400 \times .03600} = \frac{1293.6}{1.2932} = 1000.3\text{ units}$$

$$\text{Moment constant} = \frac{1329.3}{5.101 \times 24} = \frac{1329.3}{122.424} = 10.858$$

$\triangle M = .32773 - .32232 = .00541$

$$1\text{ mm.} = \frac{1329.3 \times 1.5}{\sqrt{2} \times 25.400 \times .00541 \times 5.101 \times 2} = \frac{1329.3}{1.3217} = 1005.8\text{ units}$$

Manufacturer's furnished calibration data 1mm. = 1000 units(±.4%)

APPENDIX III

AREA, MOMENT OF INERTIA, SECTION MODULUS,

and

MODEL DIMENSION CALCULATIONS

and

GRAPH

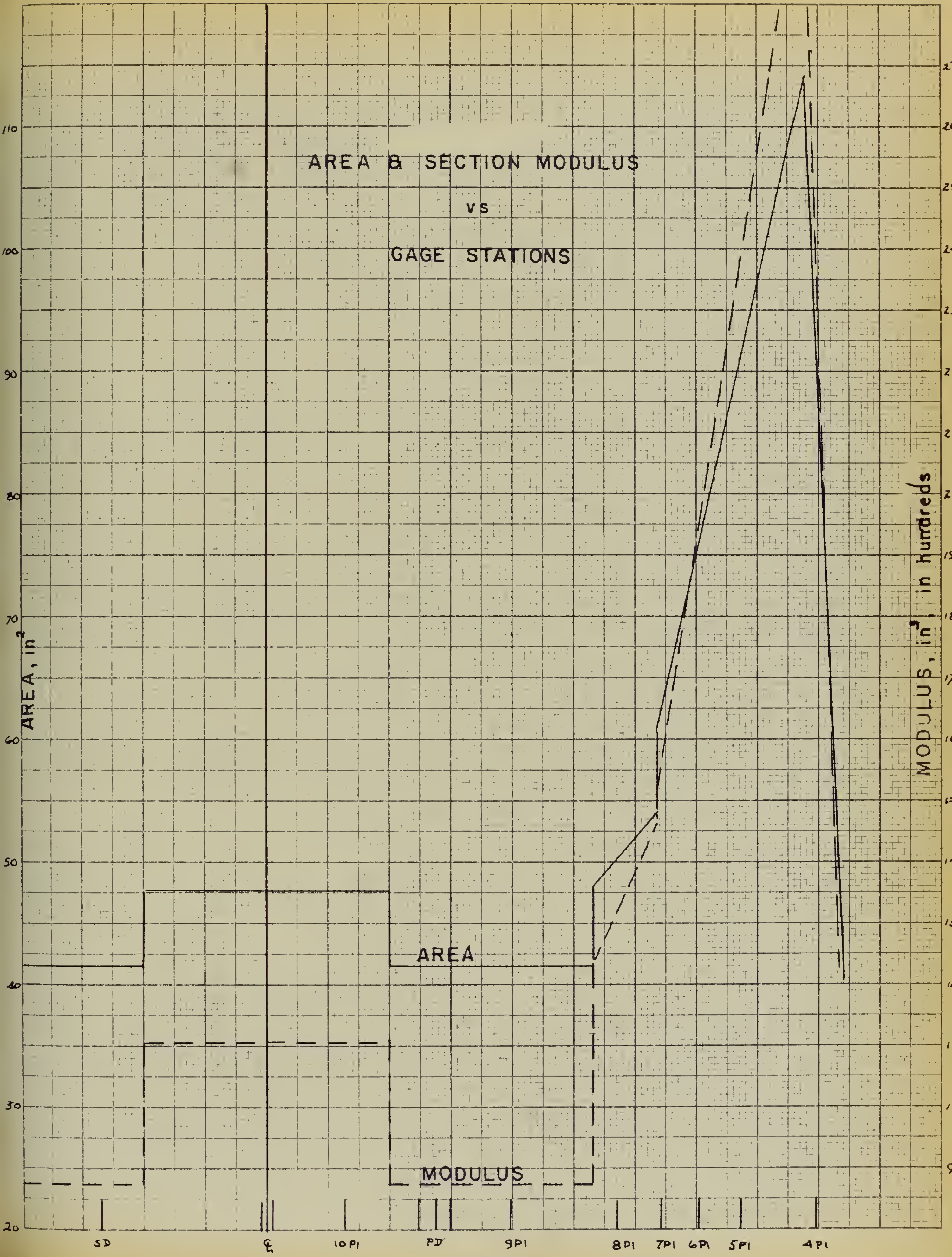
SUMMARY OF AREAS, MOMENTS OF INERTIA, SECTION MODULI, and MODEL DIMENSIONS

Section	A in^2	k	I in^4	Z in^3	D_m	d_m in
1	115.24	39.25	139,175	3545.9	51.823	1.036
2b	111.29	39.25	133,169	3392.8	51.166	1.023
2t	100.67	43.06	115,241	2676.3	48.663	.973
3b	97.71	42.97	110,931	2581.6	48.049	.961
3t	87.63	38.94	97,106	2493.7	45.967	.919
4	76.29	38.94	80,214	2059.9	43.127	.863
5	67.29	38.75	66,631	1719.5	40.541	.811
Port knee	115.78	70.40	215,389	3059.5	59.943	1.199
A	47.96	41.74	46,185	1106.5	35.878	.718
B	41.61	42.26	37,081	877.5	33.347	.667
C	48.11	37.02	45,680	1233.9	35.747	.715
D	54.11	37.16	54,400	1463.9	37.807	.756
E	66.61	41.06	62,094	1512.3	39.599	.792
F	73.50	51.00	107,837	2114.4	47.591	.952
Stbd knee	82.47	58.16	161,648	2779.4	54.474	1.089

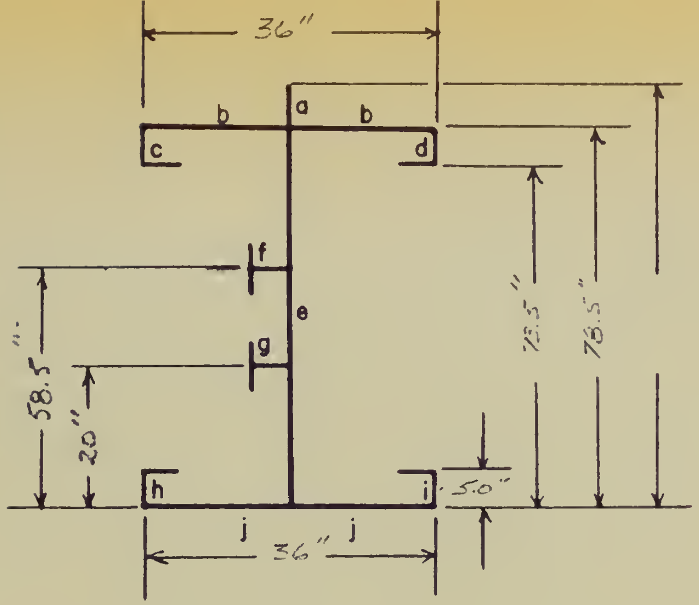
* $.02D_m = d_m$

d_m = model width

* .02 (See Appendix I)



AREA & SECTION MODULUS vs GAGE STATIONS



SECTION 1

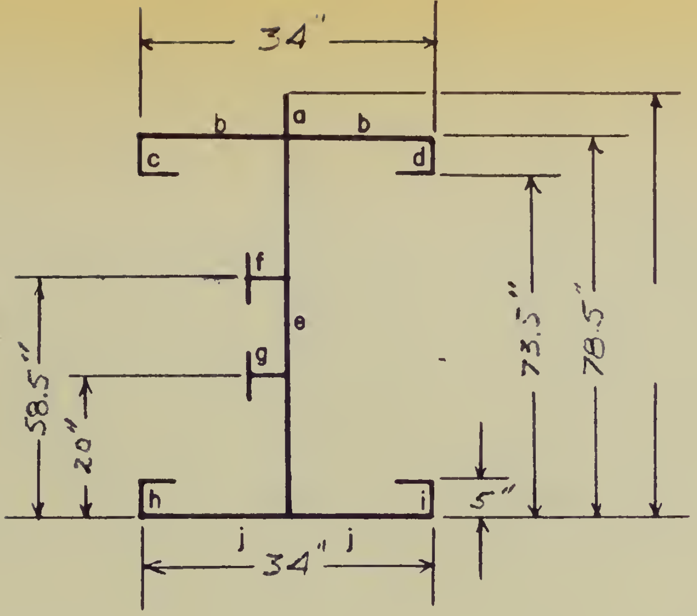
	AREA	ARM	MOMENT	$\bar{I}_o$	k′	Ak^2	I
a	–	–	–	–	–	–	–
b	36.0	78.0	2808.0	3	38.75	54056	54059
c	3.25	74.83	243.2	5	35.58	4114	4119
d	3.25	74.83	243.2	5	35.58	4114	4119
e	28.69	39.25	1126.08	13991	0	0	13991
f	.8	58.44	46.75	0	19.19	295	295
g	.8	20.06	16.05	0	19.19	295	295
h	3.25	3.67	11.93	5	35.58	4114	4119
i	3.25	3.67	11.93	5	35.58	4114	4119
j	36.0	.50	18.00	3	38.75	54056	54059
SUM	115.29	39.25	4525.14	14017		125158	139175

$D_m = \sqrt[3]{I} = 51.825$

SCANTLINGS

a	
b	t = 1.0" , w = 36"
c	4" x 3" x ½" L
d	do
e	t = .375" , l = 76.5"
f	3½" x 2.28" x 2.74# J&L Tee cut from 7" x 5.48# J&L I
g	do
h	4" x 3" x ½" L
i	do
j	t = 1.0" , w = 36"

MODEL WIDTH CALCULATIONS



Section 2B

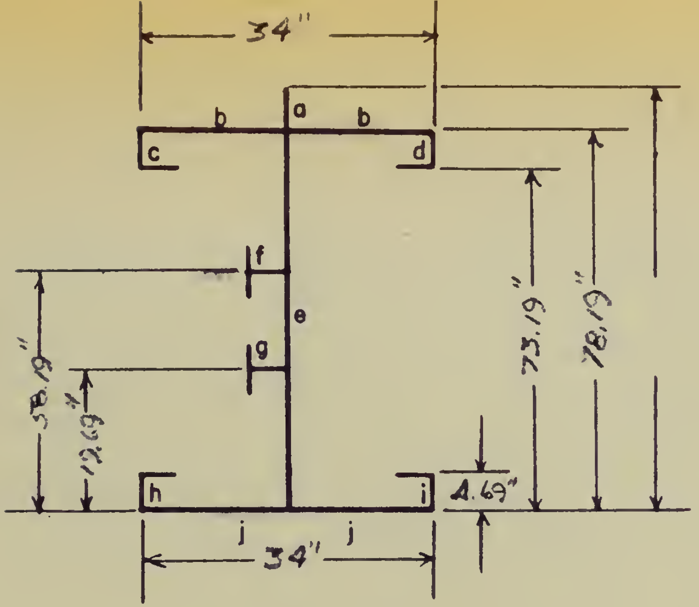
	AREA	ARM	MOMENT	Io	K	Ak^2	I
a	–	–	–	–	–	–	–
b	34.0	78	2652.0	3	38.75	51053	51056
c	3.25	74.83	243.20	5	35.58	4114	4119
d	3.25	74.83	243.20	5	35.58	4114	4119
e	28.69	39.25	1126.08	13991	0	0	13991
f	.8	58.44	46.75	0	19.19	295	295
g	.8	20.06	16.05	0	19.19	295	295
h	3.25	3.67	11.93	5	35.58	4114	4119
i	3.25	3.67	11.93	5	35.58	4114	4119
j	34.0	.50	17.00	3	38.75	51053	51056
SUM	111.29	39.25	4368.14	14017		119152	133169

$D_m = \sqrt[3]{I} = 51.166$

SCANTLINGS

a	
b	t = 1.0", w = 34"
c	See Section 1
d	do
e	t = .375", h = 76.5"
f	See Section 1
g	do
h	do
i	do
j	t = 1.0", w = 34"

MODEL WIDTH CALCULATIONS



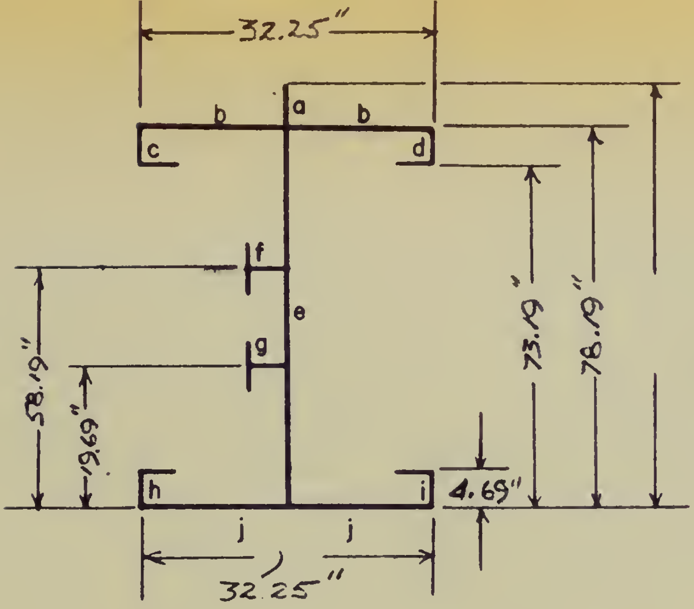
SECTION 2_T

	AREA	ARM	MOMENT	I_o	k'	Ak^2	I
a	–	–	–	–	–	–	–
b	34.0	77.69	2641.46	3	34.63	40774	40777
c	3.25	74.52	242.19	5	31.46	3217	3222
d	3.25	74.52	242.19	5	31.46	3217	3222
e	28.69	38.94	1117.19	13991	4.12	487	14478
f	.80	58.13	46.50	0	15.07	182	182
g	.80	19.75	15.80	0	23.31	435	435
h	3.25	3.36	10.92	5	39.70	5122	5127
i	3.25	3.36	10.92	5	39.70	5122	5127
j	23.38	.34	7.95	3	42.72	42668	42671
SUM	100.67	43.06	4335.12	14017		101224	115241

$D_m = \sqrt[3]{I} = 48.663$

SCANTLINGS

a	
b	t = 1.0" , w = 34"
c	SEE SECTION 1
d	do
e	t = .375 , h = 76.5"
f	SEE SECTION 1
g	do
h	do
i	do
j	t = .6875" , w = 34"



SECTION 3_B

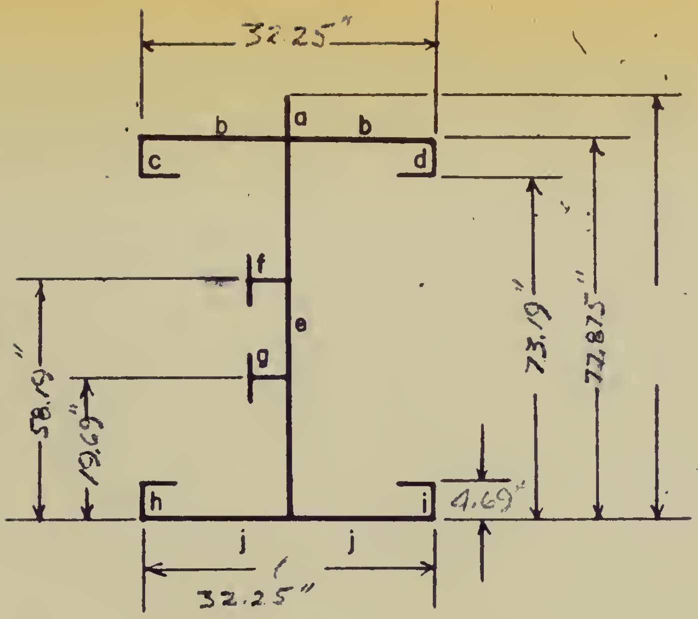
	AREA	ARM	MOMENT	$\bar{I}_o$	K	Ak^2	I
a	–	–	–	–	–	–	–
b	32.25	77.69	2505.50	3	34.72	38877	38880
c	3.25	74.52	242.19	5	31.55	3235	3240
d	3.25	74.52	242.19	5	31.55	3235	3240
e	28.69	38.94	1117.19	13991	4.03	466	14457
f	.80	58.13	46.50	0	15.16	184	184
g	.80	19.75	15.80	0	23.22	431	431
h	3.25	3.36	10.92	5	39.61	5099	5104
i	3.25	3.36	10.92	5	39.61	5099	5104
j	22.17	.34	7.54	1	42.63	40290	40291
SUM	97.71	42.97	4198.75	14015		96916	110931

$D_m = \sqrt[3]{I} = 48.049$

SCANTLINGS

a	
b	t = 1.0", w = 32.25"
c	SEE SECTION 1
d	do
e	t = .375, h = 76.5
f	SEE SECTION 1
g	do
h	do
i	do
j	t = .6875", w = 32.25"

MODEL WIDTH CALCULATIONS



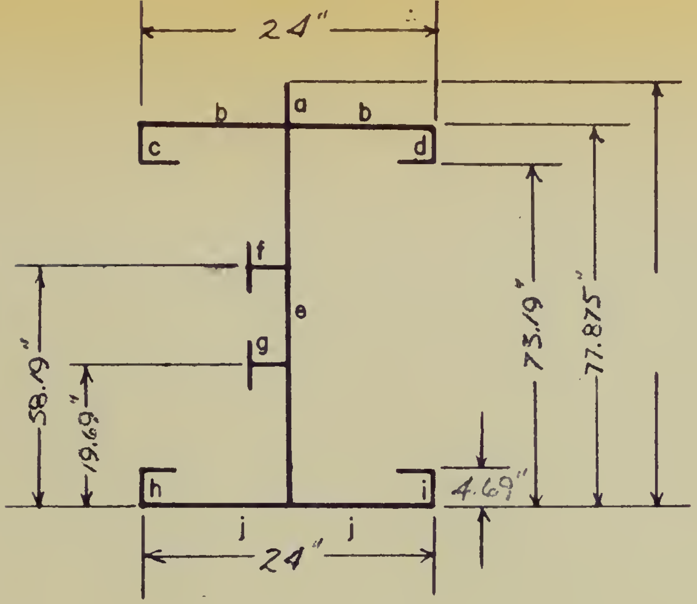
SECTION 3_T

	AREA	ARM	MOMENT	Io	K	Ak^2	I
a	—	—	—	—	—	—	—
b	22.17	77.53	1718.84	1	38.59	33015	33016
c	3.25	74.52	242.19	5	35.58	4114	4119
d	3.25	74.52	242.19	5	35.58	4114	4119
e	28.69	38.94	1117.19	13991	0	0	13991
f	.80	58.13	46.50	0	19.19	295	295
g	.80	19.75	15.80	0	19.19	295	295
h	3.25	3.36	10.92	5	35.58	4114	4119
i	3.25	3.36	10.92	5	35.58	4114	4119
j	22.17	.34	7.54	1	38.60	33032	33033
SUM	87.63	38.94	3412.09	14013		83093	97106

$D_m = \sqrt[3]{I} = 45.967$

SCANTLINGS

a	
b	t = .6875" , w = 32.25"
c	SEE SECTION 1
d	do
e	t = .375" , ℓ = 76.5"
f	SEE SECTION 1
g	do
h	do
i	do
j	t = .6875" , w = 32.25"



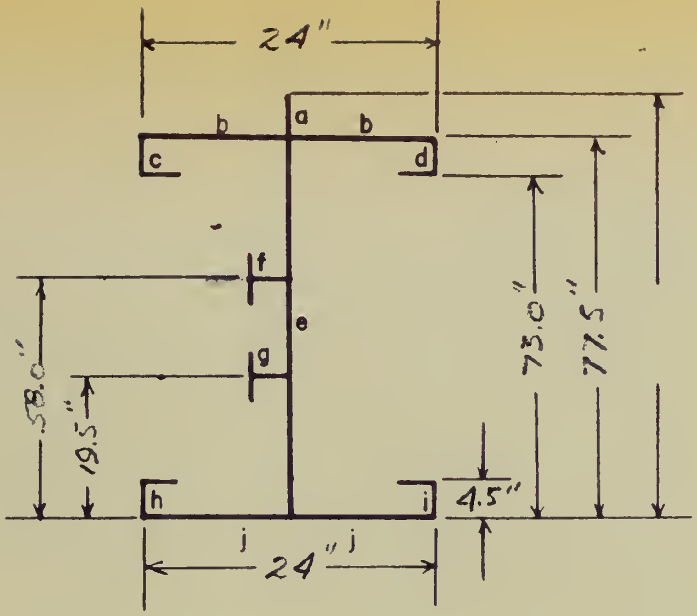
SECTION 4

	AREA	ARM	MOMENT	Io	k′	Ak²	I
a	–	–	–	–	–	–	–
b	16.5	77.53	1279.25	1	38.59	24571	24572
c	3.25	74.52	242.19	5	35.58	4114	4119
d	3.25	74.52	242.19	5	35.58	4114	4119
e	28.69	38.94	1117.19	13991	0	0	13991
f	.80	58.13	46.50	0	19.19	295	295
g	.80	19.75	15.80	0	19.19	295	295
h	3.25	3.66	10.92	5	35.58	4114	4119
i	3.25	3.66	10.92	5	35.58	4114	4119
j	16.5	.34	5.61	1	38.60	24584	24584
SUM	76.29	38.94	2970.57	14013		66201	80214

$D_m = \sqrt[3]{I} = 43.127$

SCANTLINGS

a	
b	t = .6875" , w = 24"
c	SEE SECTION 1
d	do
e	t = .375" , ℓ = 76.5"
f	SEE SECTION 1
g	do
h	do
i	do
j	t = .6875" , w = 24"



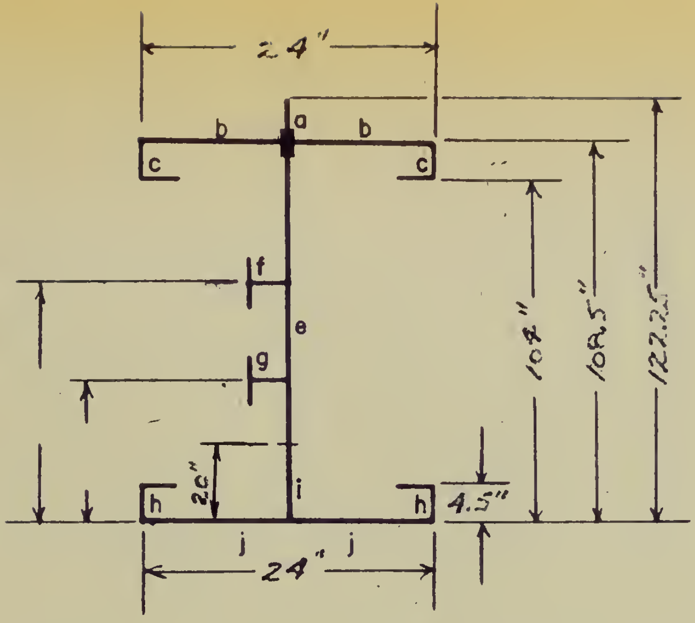
SECTION 5

	AREA	ARM	MOMENT	Io	K′	Ak²	I
a	—	—	—	—	—	—	—
b	12.00	77.25	927.00	0	38.50	17787	17787
c	3.25	74.33	241.57	5	35.58	4114	4119
d	3.25	74.33	241.57	5	35.58	4114	4119
e	28.69	38.75	1111.74	13991	0	0	13991
f	.80	57.94	46.35	0	19.19	295	295
g	.80	19.56	15.65	0	19.19	295	295
h	3.25	3.17	10.30	5	35.58	4114	4119
i	3.25	3.17	10.30	5	35.58	4114	4119
j	12.00	.25	3.00	0	38.50	17787	17787
SUM	67.29	38.75	2607.48	14011		52620	66631

$D_m = \sqrt[3]{I} = 40.541$

SCANTLINGS

a	
b	t = .5" , w = 24"
c	SEE SECTION 1
d	do
e	t = .375" , L = 76.5"
f	SEE SECTION 1
g	do
h	do
i	do
j	t = .5" , w = 24"



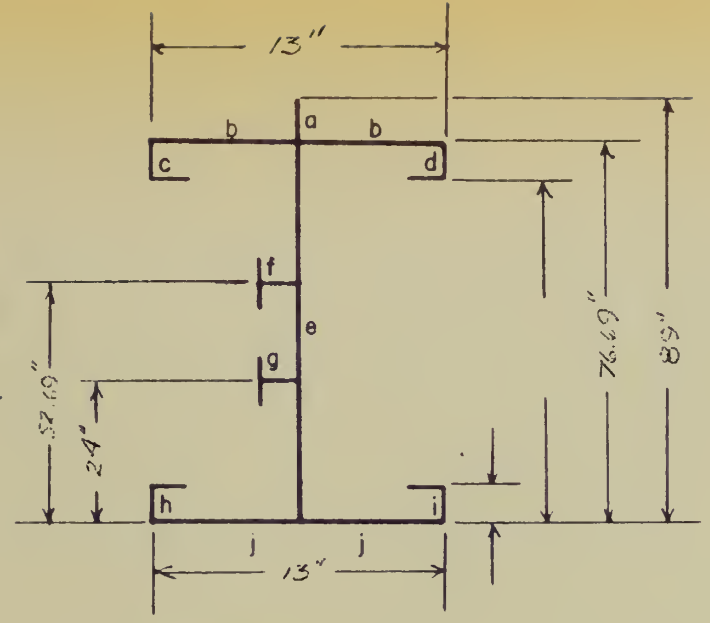
- PORT KNEE

	AREA	ARM	MOMENT	Io	K	A k^2	I
a	6.875	108.25	745.0	27	37.85	9860	9887
b	11.31	108.25	1225.0	0	37.85	16220	16220
c	6.50	105.33	684.5	10	34.95	7920	7930
X							
e	65.60	71.375	4670	65700	.975	62	65762
f	–	–	–	–	–	–	–
g	–	–	–	–	–	–	–
h	6.50	3.17	23.0	10	67.23	29380	29390
i	7.50	10.50	78.8	250	59.9	26850	27100
j	12.0	.25	3.0	0	70.15	59100	59100
SUM	115.785	70.4	8138.5	65997		149392	215389

$D_m = \sqrt[3]{I} = 59.943$

SCANTLINGS

a	t = .5" h = 6.875" F.B. doubler (2)
b	t = .472" (ave. of two deck plates) w = 24"
c	4" × 3" × ½" L (2)
X	
e	t = .75" h = 87.5"
f	
g	
h	4" × 3" × ½" L (2)
i	t = .375" h = 20"
j	t = .5" w = 24"



SECTION A

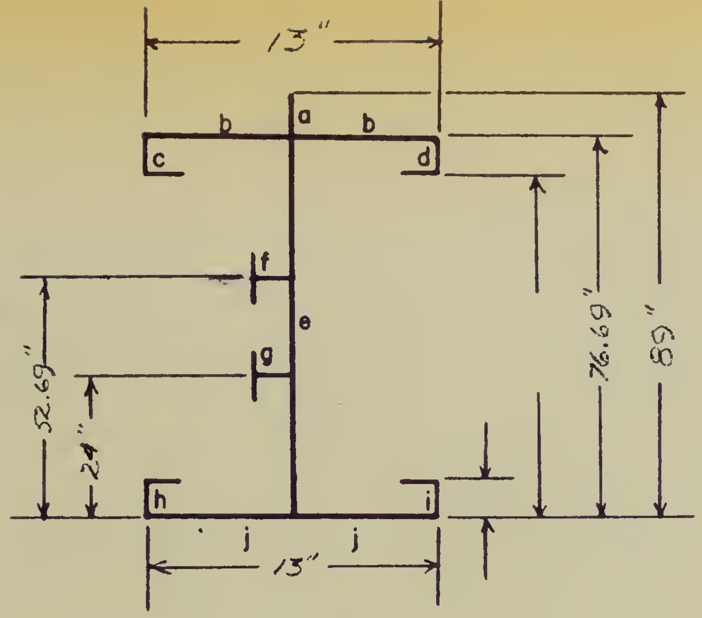
	AREA	ARM	MOMENT	I_o	k′	Ak^2	I
a	3.66	82.85	303.23	46	41.11	6186	6232
b	9.75	76.31	744.02	1	34.57	11652	11653
c	–	–	–	–	–	–	–
d	–	–	–	–	–	–	–
e	23.50	38.35	901.22	11070	3.39	270	11340
f	.65	52.63	34.21	0	9.11	54	54
g	.65	24.06	15.64	0	16.68	227	227
h	–	–	–	–	–	–	–
i	–	–	–	–	–	–	–
j	9.75	.38	3.70	0	41.36	16679	16679
SUM	47.96	41.74	2002.02	11117		35068	46185

$D_m = \sqrt[3]{I} = 35.876$

SCANTLINGS

a	t = .2969" , h = 12.31"
b	t = .75" , w = 13"
c	
d	
e	t = .3125" , h = 75.19"
f	3" × 1.84" × 2.2# J&L TEE , cut from 6" × 4.4# J&L I
g	do
h	
i	
j	t = .75" w = 13"

MODEL WIDTH CALCULATIONS



SECTION B

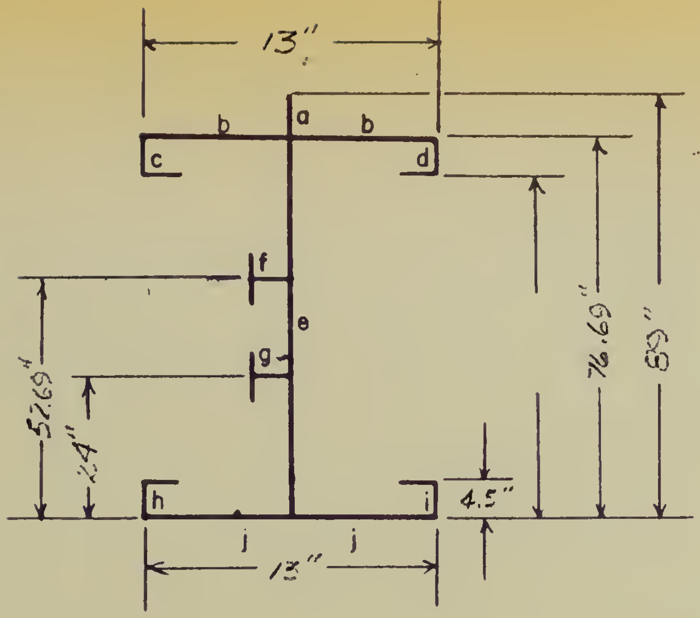
	AREA	ARM	MOMENT	Io	K′	Ak^2	I
a	3.66	82.85	303.23	46	40.59	6030	6076
b	6.50	76.44	496.86	0	34.18	7594	7594
c	–	–	–	–	–	–	–
d	–	–	–	–	–	–	–
e	23.65	38.34	906.74	11292	3.92	363	11655
f	.65	52.63	34.21	0	10.57	70	70
g	.65	24.06	15.64	0	18.20	215	215
h	–	–	–	–	–	–	–
i	–	–	–	–	–	–	–
j	6.50	.25	1.62	0	42.01	11471	11471
SUM	41.61	42.26	1758.30	11338		25743	37081

$D_m = \sqrt[3]{I} = 33.347$

SCANTLINGS

a	t = .2969", h = 12.31"
b	t = .5", w = 13"
c	
d	
e	t = .3125", h = 75.69"
f	SEE SECTION A
g	do
h	
i	
j	t = .5", w = 13"

MODEL WIDTH CALCULATIONS



SECTION C

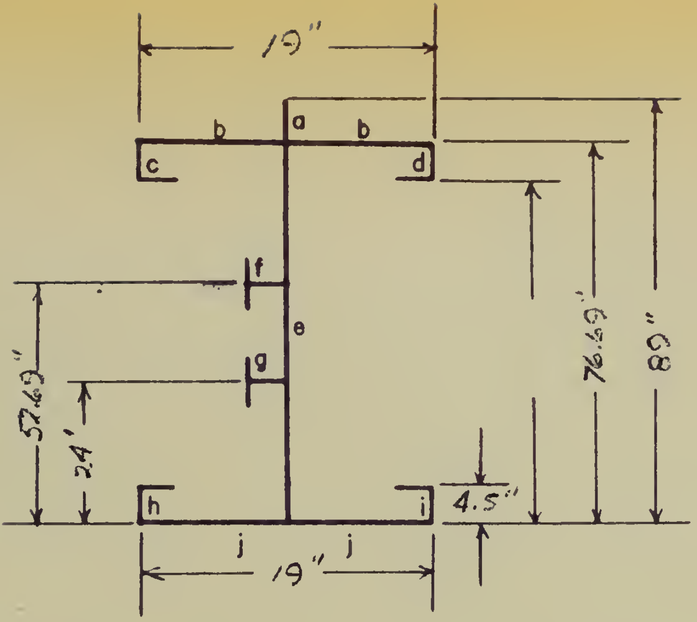
	AREA	ARM	MOMENT	Io	k′	Ak^2	I
a	3.66	82.85	303.23	46	45.83	7687	7733
b	6.50	76.44	496.56	0	39.42	10101	10101
c	-	-	-	-	-	-	-
d	-	-	-	-	-	-	-
e	23.65	38.34	906.74	11292.	1.32	41	11333
f	.65	52.63	34.21	0	15.61	158	158
g	.65	24.06	15.64	0	12.96	109	109
h	3.25	3.17	11.30	5	33.85	3724	3729
i	3.25	3.17	11.30	5	33.85	3724	3729
j	6.50	.25	1.62	0	36.77	8788	8788
SUM	48.11	37.02	1780.90	11348		34332	45660

$D_m = \sqrt[3]{I} = 35.747$

SCANTLINGS

a	t = .2969", h = 12.31"
b	t = .5", w = 13"
c	
d	
e	t = .3125", h = 75.69"
f	SEE SECTION A
g	do
h	4" x 3" x ½" L
i	do
j	t = .5", w = 13"

MODEL WIDTH CALCULATIONS



SECTION D

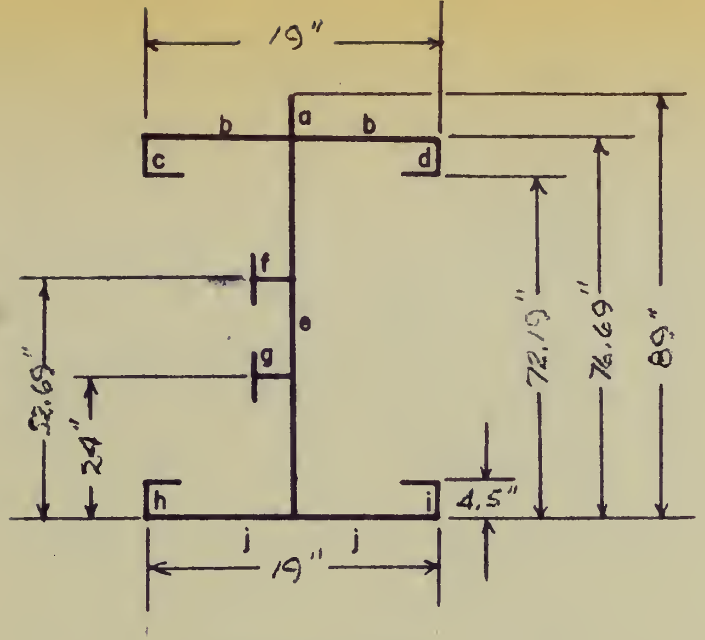
	AREA	ARM	MOMENT	Io	k′	A k^2	I
a	3.66	8285	303.23	46	45.69	7641	7687
b	9.50	76.44	726.18	0	39.28	14658	14658
c	–	–	–	–	–	–	–
d	–	–	–	–	–	–	–
e	23.65	38.34	90674	11292	1.18	33	11325
f	.65	52.63	34.21	0	15.47	156	156
g	.65	24.06	15.64	0	13.10	112	112
h	3.25	3.17	11.30	5	33.99	3755	3760
i	3.25	3.17	11.30	5	33.99	3755	3760
j	9.50	.25	2.38	0	36.91	12942	12942
SUM	54.11	37.16	2010.98	11348		43052	54400

$D_m = \sqrt[3]{I} = 37.807$

SCANTLINGS

a	t = .2969", h = 12.31"
b	t = .5, h = 19"
c	
d	
e	t = .3125", h = 75.69"
f	SEE SECTION A
g	do
h	SEE SECTION C
i	do
j	t = .5", w = 19"

MODEL WIDTH CALCULATIONS



SECTION E

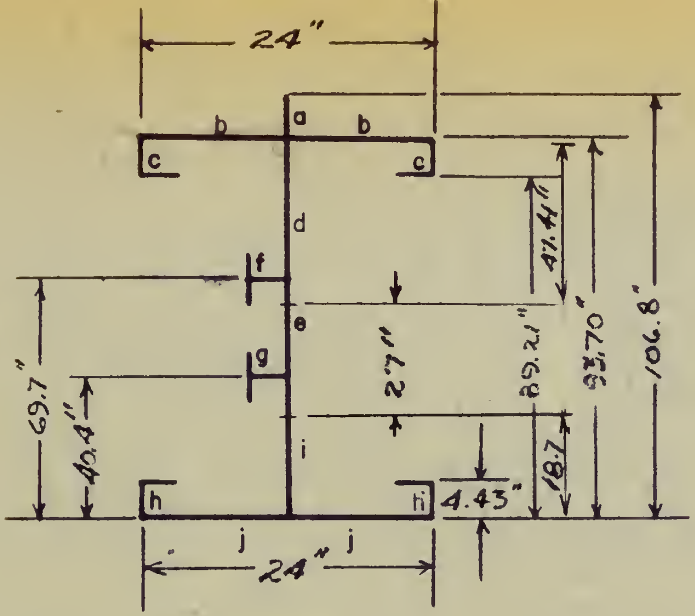
	AREA	ARM	MOMENT	Io	K	Ak²	I
a	3.66	82.85	303.23	46	41.79	6392	6438
b	9.50	76.44	726.18	0	35.38	11892	11892
c	3.25	73.52	238.94	5	32.46	3424	3429
d	3.25	73.52	238.94	5	32.46	3424	3429
e	23.65	38.34	906.74	11292	2.72	175	11467
f	.65	52.63	34.21	0	11.57	87	87
g	.65	24.06	15.64	0	17.00	188	188
h	3.25	3.17	11.30	5	37.89	4666	4671
i	3.25	3.17	11.30	5	37.89	4666	4671
j	9.50	.25	2.38	0	40.81	15822	15822
SUM	60.61	41.06	2488.86	11358		50736	62094

$D_m = \sqrt[3]{I} = 39.599$

SCANTLINGS

a	t = .2969" , ℓ = 12.31"
b	t = .5 , w = 19"
c	4" x 3" x ½" L
d	do
e	t = .3125" , ℓ = 75.69"
f	SEE SECTION A
g	do
h	SEE SECTION C
i	do
j	t = .5" , w = 19"

MODEL WIDTH CALCULATIONS



SECTION F

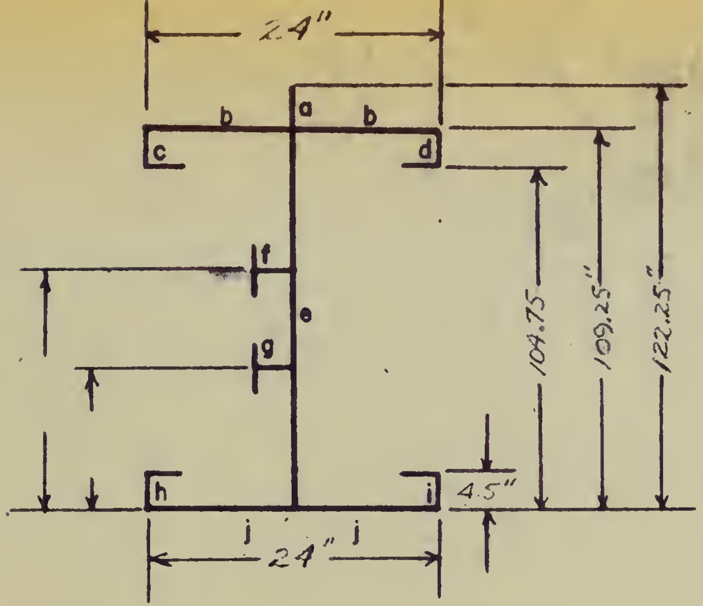
	AREA	ARM	MOMENT	Io	K	Ak²	I
a	3.89	100.25	389.97	56	49.25	9435	9491
b	11.78	93.45	1100.84	0	42.45	21228	21228
c	6.50	90.54	588.51	10	39.54	10162	10172
d	17.78	69.51	1235.89	3330	18.51	6097	9427
e	8.44	32.29	272.53	513	18.71	2955	3468
f	.65	69.60	45.24	0	19.60	250	250
g	.65	40.30	26.20	0	10.70	74	74
h	6.50	3.10	20.15	10	47.90	14914	14924
i	7.01	9.56	67.02	195	41.44	12038	12233
j	10.30	.21	2.16	0	50.79	26,570	26570
SUM	73.50	51.00	3748.51	4114		103,723	107857

$D_m = \sqrt[3]{I} = 47.591$

SCANTLINGS

a	t = .2969"	h = 13.1"
b	t = .491"	w = 24"
c	4" x 3" x ½" L	(2)
d	t = .375"	h = 47.409"
e	t = .3125"	h = 27"
f	3" x 1.84" x 2.2# J&L TEE, cut from 6" x 4.4# J&L I	
g	do	
h	4" x 3" x ½" L	(2)
i	t = .375"	h = 18.271"
j	t = .429"	w = 24"

MODEL WIDTH CALCULATIONS



KNEE - STBD

	AREA	ARM	MOMENT	Io	K	Ak^2	I
a	4.88	115.75	564.86	69	57.59	16185	16254
b	12.00	109.00	1308.00	0	50.84	31016	31016
c	3.25	105.08	341.51	5	46.92	7155	7160
d	3.25	105.08	341.51	5	46.92	7155	7160
e	40.59	54.62	2217.03	39640	3.54	509	40149
f	-	-	-	-	-	-	-
g	-	-	-	-	-	-	-
h	3.25	3.17	10.30	5	54.99	9828	9833
i	3.25	3.17	10.30	5	54.99	9828	9833
j	12.00	.25	3.00	0	57.91	40,243	40243
SUM	82.47	58.16	4796.51	39729		121919	161648

$D_m = \sqrt[3]{I} = 54.474$

SCANTLINGS

a	$t = .375"$, $\ell = 13"$
b	$t = .5"$, $w = 24"$
c	SEE SECTION E
d	do
e	$t = .375"$, $\ell = 108.25"$
f	
g	
h	SEE SECTION C
i	do
j	$t = .5"$, $w = 24"$

MODEL WIDTH CALCULATIONS

APPENDIX IV

PLASTIC DATA

CHARACTERISTICS OF PLASTIC USED IN MODEL

A sample of the plastic supplied with the Beggs Deformeter equipment was taken to the Material Laboratory, New York Naval Shipyard, Brooklyn, N.Y., for analysis. It was determined to be polymerized methyl methacrylate. Manufactured by DuPont and Rohm & Haas Co. it is known as "Lucite" and "Plexiglas" respectively. The sample of plastic is Plexiglas and data relating to its mechanical properties was taken from Rohm & Haas Co. pamphlets (see References). The data presented here is that pertinent only to conditions to which the model was exposed and represents average values.

The following characteristics were deemed useful for possible determination of correction factors to represent changes due to the varying environmental conditions. It is questionable, however, if such correction factors would enhance the accuracy of the final results of the model tests, or whether they would represent accurately the characteristics of the particular plastic specimen used.

a. Amount thickness variation: 10% within the sheet

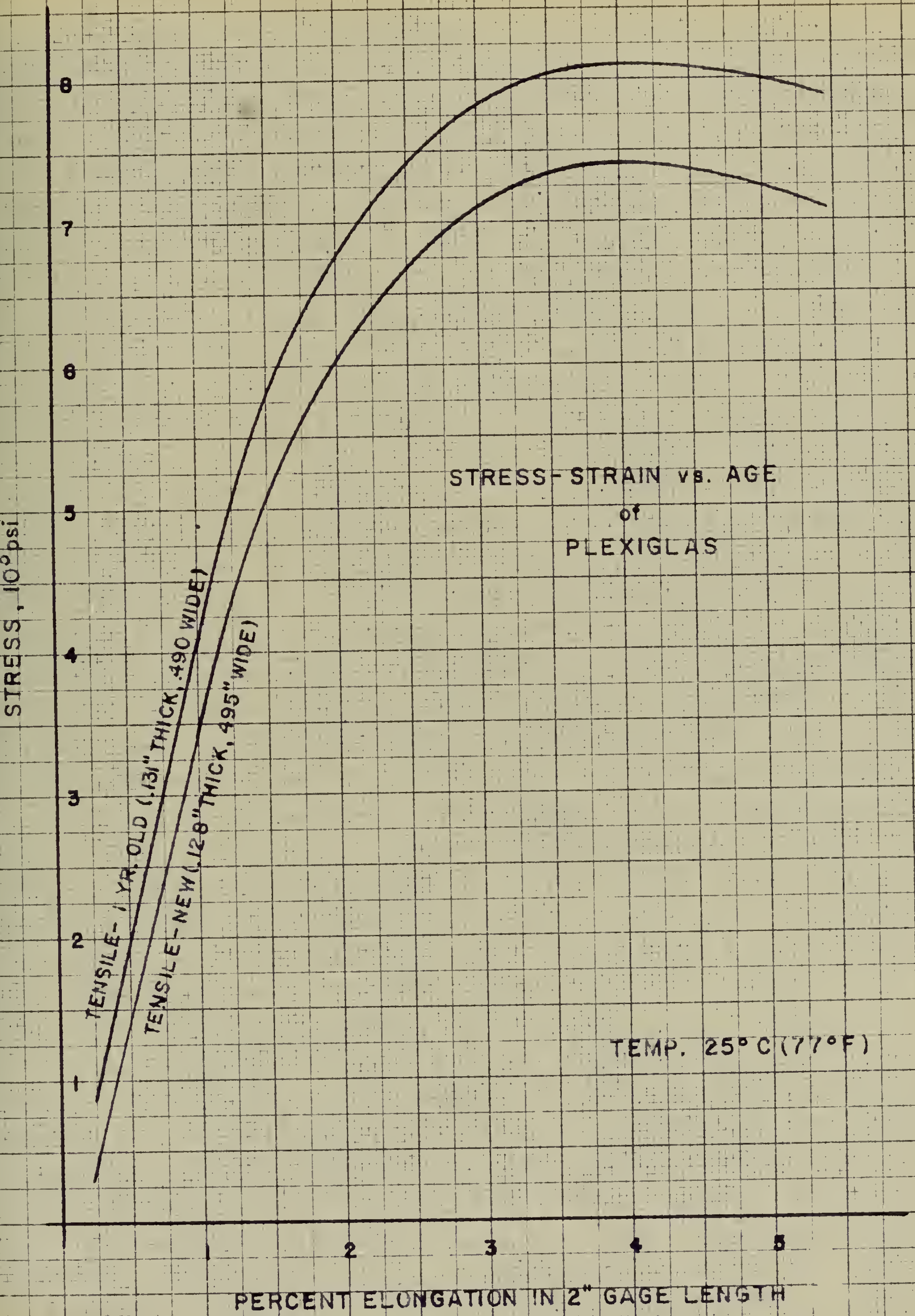
b. Moduli of elasticity: @ 25°C (77°F)

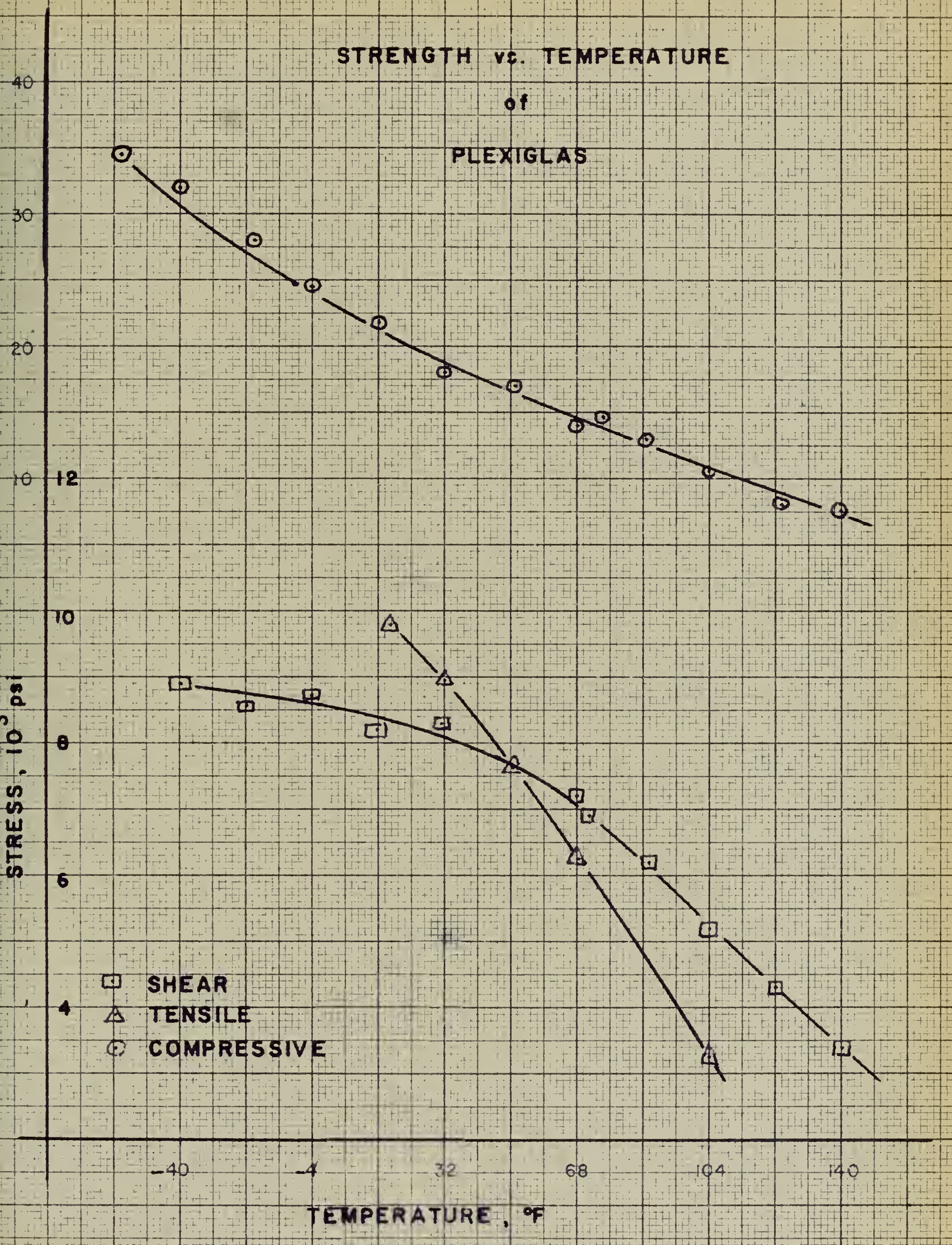
Tension	400,000 psi
Flexure	380,000 psi
Compression	280,000 psi
Shear	125,000 psi

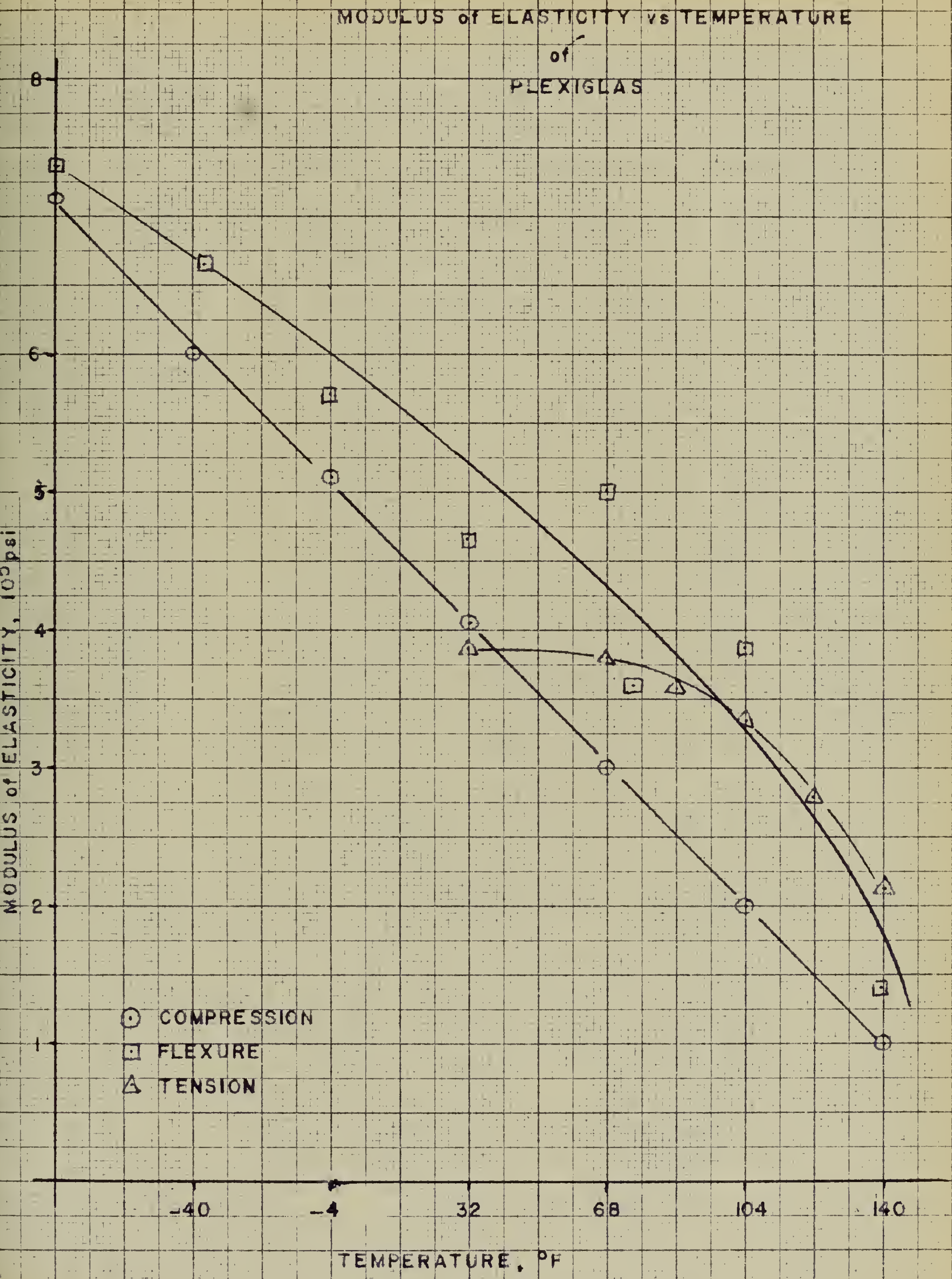
c. Cold flow or creep: Limiting allowable stress at which Plexiglas does not flow more than 10% in 100,000 hours at 25°C is approximately 5,000 psi for indoor service.

Plexiglas is a thermoplastic resin. Its properties vary with temperature. These properties also vary with age, conditioning, and previous history of the sample. Fortunately, these latter variations are only slight, if not negligible, both because of Plexiglas' chemical stability and because it absorbs very little moisture. Litte is known of the previous history of the sample used other than it is more than one year old. Based on physical appearances it was assumed that there was no application of conditioning or prestressing. Variations occur with changes in thickness of the sample. Yet, because the plastic used in the model was from sheets of essentially constant thickness (within the limits of the aforementioned 10% margin) it was felt that these variations were negligible.

The following graphs, of data taken from tests conducted by Rohm & Haas Co. on cast acrylic sheets at a straining rate of .050 in. per minute (and at 25°C (77°F) for the tests relating age and property variance), represent changes in the strength characteristics of Plexiglas due to changes in Temperature and Age.


STRESS-STRAIN vs. AGE
of
PLEXIGLAS
TENSILE- 1 YR. OLD (.131" THICK, .490 WIDE)
TENSILE-NEW (.128" THICK, .495" WIDE)
TEMP. 25° C (77°F)
STRESS, 10^3 psi
8
7
6
5
4
3
2
1
1
2
3
4
5
PERCENT ELONGATION IN 2" GAGE LENGTH


STRENGTH vs. TEMPERATURE
of
PLEXIGLAS
STRESS, 10^3 psi
40
30
20
10
12
10
8
6
4
-40
-4
32
68
104
140
TEMPERATURE, °F
□ SHEAR
△ TENSILE
⊙ COMPRESSIVE


MODULUS of ELASTICITY vs TEMPERATURE
of
PLEXIGLAS
MODULUS of ELASTICITY, 10^5 psi
8
6
5
4
3
2
1
-40
-4
32
68
104
140
TEMPERATURE, °F
⊙ COMPRESSION
⊡ FLEXURE
△ TENSION

Small local stresses may be set up by sawing or machining Plexiglas, but these are of no great importance unless a considerable area of the material is involved. The layer of local stress can be materially reduced by use of slow cutting speeds, sharp tools, and either oil or water coolants applied to the cut. Furthermore, by proper and careful sanding or filing of the cut surfaces it is felt that the layers of stressed area were removed and that the finished model was essentially stress-free throughout its cross-section. All edges were left smooth tb the touch.

APPENDIX V

DEFORMETER READINGS

SUMMARY OF DEFORMETER DATA

POINT	HORIZ. COEFF.	RUN#1 PORT FOOT	RUN #2 10PI	RUN #3 9PI	RUN #4 7PI	RUN #5 SD
SD	THRUST	0.259	- 0.538	- 0.534	- 0.553	- 0.536
	SHEAR	0.605	- 0.295	- 0.299	- 0.266	0.670
	MOMENT	-69.412	25.783	-10.930	-45.664	81.495
℄ S	THRUST	0.453	- 0.607	- 0.605	- 0.605	- 0.559
	SHEAR	0.627	- 0.548	- 0.475	- 0.435	0.515
	MOMENT	-58.807	68.806	2.630	-49.321	35.914
PD	THRUST	0.650	- 0.535	- 0.531	- 0.562	- 0.544
	SHEAR	0.585	0.284	- 0.666	- 0.651	0.331
	MOMENT	-33.743	61.445	46.237	-32.446	4.026
8PI	THRUST	0.843	- 0.373	- 0.370	- 0.354	- 0.357
	SHEAR	0.331	0.095	0.143	- 0.840	0.141
	MOMENT	- 8.450	20.031	36.698	19.258	- 6.039
4PI	THRUST	0.997	- 0.001	0.011	- 0.006	- 0.007
	SHEAR	0.015	0.003	0.003	0.002	0.003
	MOMENT	4.117	0.613	- 0.212	0.660	0.332
2PI	THRUST	0.983	- 0.001	0.002	0.003	- 0.002
	SHEAR	0.034	- 0.002	0.005	0.010	- 0.003
	MOMENT	0.838	0.418	- 0.258	0.372	0.120
GAGE	SHEAR*R	0.000	0.605	0.197	0.108	0.670
	SHEAR*L	- 1.000	- 0.610	- 0.748	- 0.855	- - - -

RUN #1

BEGGS DEFORMETER
DATA SHEET

RECORDER Perry
OBSERVER Larson

POINT # SD
MICROSCOPE # 107 AL

SHEET # 1
DATE 7April 1955

PLUG	HORIZONTAL	VERTICAL
NORMAL	1854.3	1952.3
	1855.1	1951.1
	1854.8	1951.5
	1857.6	1952.5
SUM	7421.8	7807.4
AVERAGE	1855.4	1951.6

PLUG	HORIZONTAL	VERTICAL	PLUG	HORIZONTAL	VERTICAL
THRUST	1706.0	1912.9	THRUST REVERSED	2040.4	1983.7
	1704.4	1913.0		2038.0	1991.9
	1701.5	1911.2		2040.5	1993.2
	1700.9	1909.1		2036.5	1988.2
SUM	6812.8	7646.2	SUM	8155.4	7957.0
AVERAGE	1703.2	1911.5	AVERAGE	2038.9 1703.2 +335.7	1989.2 1911.5 +77.7
DIFFERENCE	+335.7	+77.7			
CONSTANT	1296.7	1296.7			
COEFFICIENT	+.259	+.060			
SHEAR	1431.5	1626.1	SHEAR REVERSED	2203.2	2294.5
	1426.4	1622.4		2203.9	2295.4
	1431.0	1624.3		2206.6	2294.6
	1425.5	1622.6		2207.9	2294.9
SUM	5714.4	6495.4	SUM	8821.6	9179.4
AVERAGE	1428.6	1623.8	AVERAGE	2205.4 1428.6 +776.8	2294.8 1623.8 +671.0
DIFFERENCE	+776.8	+671.0			
CONSTANT	1283.2	1283.2			
COEFFICIENT	+.605	+.522			
MOMENT	2227.2	2444.0	MOMENT REVERSED	1482.9	1493.7
	2230.2	2442.8		1486.0	1491.9
	2230.5	2441.0		1482.3	1490.2
	2230.2	2439.2		1478.9	1492.1
SUM	8917.1	9767.0	SUM	5930.1	5967.9
AVERAGE	2229.3	2441.8	AVERAGE	1482.5 2229.3 −746.8	1492.0 2441.8 −949.8
DIFFERENCE	−746.8	−949.8			
CONSTANT	10.759	10.759			
COEFFICIENT	−69.412	−88.280			

RUN #1
BEGGS DEFORMETER
DATA SHEET

RECORDER Perry
OBSERVER Larson

POINT # ℄S
MICROSCOPE # 107AL

SHEET # 2
DATE 11 April 1955

PLUG	HORIZONTAL	VERTICAL
NORMAL	1413.2	1506.3
	1411.8	1510.3
	1411.3	1512.3
	1415.8	1515.2
SUM	5652.1	6044.1
AVERAGE	1413.0	1511.0

PLUG	HORIZONTAL	VERTICAL	PLUG	HORIZONTAL	VERTICAL
THRUST	1115.8	1443.5	THRUST REVERSED	1706.9	1532.3
	1117.5	1439.3		1702.6	1533.4
	1118.9	1441.1		1706.8	1530.7
	1120.5	1439.8		1707.0	1530.6
SUM	4472.7	5763.7	SUM	6823.3	6127.0
AVERAGE	1118.2	1440.9	AVERAGE	1705.8	1531.8
DIFFERENCE	+ 587.6	+ 90.9		1118.2	1440.9
CONSTANT	1296.7	1296.7		+587.6	+ 90.9
COEFFICIENT	+ .453	+.070			
SHEAR	979.3	1158.3	SHEAR REVERSED	1804.9	1792.0
	982.0	1162.1		1796.6	1788.3
	983.5	1158.0		1800.3	1789.5
	983.2	1160.9		1801.6	1785.3
SUM	3928.0	4639.3	SUM	7203.4	7155.1
AVERAGE	982.0	1159.8	AVERAGE	1800.8	1788.8
DIFFERENCE	+ 818.8	+ 629.0		982.0	1159.8
CONSTANT	1283.2	1283.2		+818.8	+629.0
COEFFICIENT	+ .627	+.490			
MOMENT	1759.8	1970.1	MOMENT REVERSED	1128.0	1025.5
	1760.9	1971.7		1124.0	1021.1
	1755.1	1970.1		1124.0	1021.2
	1756.6	1969.7		1125.3	1019.1
SUM	7032.4	7881.6	SUM	4501.3	4086.9
AVERAGE	1758.1	1970.4	AVERAGE	1125.4	1021.7
DIFFERENCE	- 632.7	-948.7		1758.1	1970.4
CONSTANT	10.759	10.759		- 632.7	- 948.7
COEFFICIENT	- 58.807	-88.177			

RUN #1

BEGGS DEFORMETER

DATA SHEET

RECORDER Perry

OBSERVER Larson

POINT # PD

MICROSCOPE # 105 AL

SHEET # 3

DATE 7 April 1955

PLUG	HORIZONTAL	VERTICAL
NORMAL	1893.0	2050.0
	1895.1	2051.3
	1893.0	2050.9
	1894.2	2049.9
SUM	7575.3	8202.1
AVERAGE	1893.8	2050.5

PLUG	HORIZONTAL	VERTICAL	PLUG	HORIZONTAL	VERTICAL
THRUST	1488.0	2003.2	THRUST REVERSED	2324.8	2099.5
	1483.3	2008.0		2323.5	2102.2
	1481.2	2007.7		2316.3	2105.4
	1482.3	2007.0		2313.8	2102.5
SUM	5934.8	8025.9	SUM	9278.4	8409.6
AVERAGE	1483.7	2006.5	AVERAGE	2319.6	2102.4
DIFFERENCE	+ 835.9	+ 95.9		1483.7	2006.5
CONSTANT	1288.5	1288.5		+835.9	+95.9
COEFFICIENT	+.650	+.075			
SHEAR	1477.2	1733.0	SHEAR REVERSED	2227.5	2404.6
	1476.5	1736.5		2227.4	2406.0
	1473.7	1733.9		2230.4	2407.4
	1475.8	1739.5		2226.0	2407.0
SUM	5903.2	6942.9	SUM	8911.3	9625.0
AVERAGE	1475.8	1735.7	AVERAGE	2227.8	2406.2
DIFFERENCE	+ 752.0	+ 670.5		1475.8	1735.7
CONSTANT	1289.0	1289.0		+752.0	+670.5
COEFFICIENT	+.585	+.521			
MOMENT	2075.3	2544.0	MOMENT REVERSED	1709.3	1580.4
	2075.3	2545.0		1707.9	1582.2
	2071.5	2544.0		1706.8	1581.8
	2070.2	2546.3		1706.9	1579.8
SUM	8292.3	10179.3	SUM	6830.9	6324.2
AVERAGE	2073.1	2544.8	AVERAGE	1707.7	1581.1
DIFFERENCE	- 365.4	- 963.7		2073.1	2544.8
CONSTANT	10.829	10.829		- 365.4	- 963.7
COEFFICIENT	- 33.743	- 88.993			

RUN #1

BEGGS DEFORMETER
DATA SHEET

RECORDER Perry
OBSERVER Larson

POINT # 8 PI
MICROSCOPE # 108 AL

SHEET # 4
DATE 11 April 1955

PLUG	HORIZONTAL	VERTICAL
NORMAL	1505.1	1449.7
	1508.0	1448.7
	1511.3	1450.2
	1507.5	1446.2
SUM	6031.9	5794.8
AVERAGE	1508.0	1448.7

PLUG	HORIZONTAL	VERTICAL	PLUG	HORIZONTAL	VERTICAL
THRUST	961.8	1368.9	THRUST REVERSED	2054.0	1470.1
	964.7	1370.3		2051.3	1469.6
	968.3	1372.7		2048.6	1468.3
	965.1	1368.3		2050.9	1467.8
SUM	3759.9	5480.2	SUM	8204.8	5875.8
AVERAGE	965.0	1370.1	AVERAGE	2051.2	1468.9
DIFFERENCE	+1086.2	+98.8		965.0	1370.1
CONSTANT	1288.5	1288.5		+1086.2	+98.8
COEFFICIENT	+ .843	+.077			
SHEAR	1269.9	1086.2	SHEAR REVERSED	1728.5	1729.7
	1264.9	1090.2		1728.3	1728.5
	1265.1	1087.3		1729.8	1729.7
	1265.3	1086.5		1729.8	1730.5
SUM	5065.2	4370.2	SUM	6916.4	6918.4
AVERAGE	1266.3	1092.6	AVERAGE	1729.1	1729.6
DIFFERENCE	+462.8	+637.0		1266.3	1092.6
CONSTANT	1289.0	1289.0		+462.8	+637.0
COEFFICIENT	+.331	+.494			
MOMENT	1571.7	1899.9	MOMENT REVERSED	1481.9	949.4
	1568.9	1901.0		1478.9	945.8
	1572.3.	1900.3		1477.3	946.0
	1573.1	1900.2		1482.0	948.2
SUM	6286.0	7601.4	SUM	5920.1	3789.4
AVERAGE	1571.5	1900.3	AVERAGE	1480.0	947.3
DIFFERENCE	-91.5	-953.0		1571.5	1900.3
CONSTANT	10.829	10.829		-91.5	-953.0
COEFFICIENT	-8.450	-88.004			

RUN #1
BEGGS DEFORMETER
DATA SHEET

RECORDER Perry
OBSERVER Larson

POINT # 4PI
MICROSCOPE # 10GAL

SHEET # 5
DATE 11 April 1955

PLUG	HORIZONTAL	VERTICAL
NORMAL	1989.5	2002.1
	1990.3	1994.5
	1991.0	2001.3
	1990.2	2003.5
SUM	7961.0	7999.4
AVERAGE	1990.2	1999.8

PLUG	HORIZONTAL	VERTICAL	PLUG	HORIZONTAL	VERTICAL
THRUST	1351.6	1930.8	THRUST REVERSED	2605.0	2007.3
	1354.6	1933.9		2610.5	2003.4
	1354.7	1935.5		2612.3	2008.5
	1348.6	1930.8		2614.3	2009.1
SUM	5410.5	7731.0	SUM	10442.1	8028.3
AVERAGE	1352.6	1932.8	AVERAGE	2610.5 1352.6 +1257.9	2007.1 1932.8 +74.3
DIFFERENCE	+1257.9	+74.3			
CONSTANT	1287.6	1287.6			
COEFFICIENT	+.977	+.058			
SHEAR	1958.3	1591.5	SHEAR REVERSED	1981.5	2315.0
	1963.5	1591.5		1981.5	2316.1
	1965.5	1597.3		1981.2	2315.5
	1959.3	1595.0		1979.2	2313.3
SUM	7846.6	6375.3	SUM	7923.4	9259.9
AVERAGE	1961.6	1593.8	AVERAGE	1980.9 1961.6 +19.3	2315.0 1593.8 +721.2
DIFFERENCE	+19.3	+721.2			
CONSTANT	1293.6	1293.6			
COEFFICIENT	+.015	+.558			
MOMENT	1965.8	2458.5	MOMENT REVERSED	2008.2	1483.9
	1963.3	2455.3		2010.0	1485.1
	1965.1	2455.1		2009.8	1487.8
	1965.0	2453.8		2010.1	1483.9
SUM	7859.2	9822.7	SUM	8038.1	5940.7
AVERAGE	1964.8	2455.2	AVERAGE	2009.5 1964.8 +447	1485.2 2455.2 - 970.0
DIFFERENCE	+ 44.7	- 970.0			
CONSTANT	10.858	10.858			
COEFFICIENT	+4.117	- 89.335			

RUN #1
BEGGS DEFORMETER
DATA SHEET

RECORDER Perry
OBSERVER Larson

POINT # 2 PI
MICROSCOPE # 109 AL

SHEET # 6
DATE 7 April 1955

PLUG	HORIZONTAL	VERTICAL
NORMAL	2091.0	1597.5
	2092.9	1599.5
	2092.5	1599.1
	2091.5	1599.5
SUM	8367.4	6395.6
AVERAGE	2091.9	1598.9

PLUG	HORIZONTAL	VERTICAL	PLUG	HORIZONTAL	VERTICAL
THRUST	1459.9	1611.6	THRUST REVERSED	2720.5	1619.9
	1461.5	1610.7		2725.0	1625.3
	1460.5	1611.9		2724.1	1620.2
	1461.1	1611.0		2724.4	1622.6
SUM	5843.0	6445.2	SUM	10794.0	6488.0
AVERAGE	1460.8	1611.3	AVERAGE	2723.5	1622.0
DIFFERENCE	+1262.7	+10.7		1460.8	1611.3
CONSTANT	1287.6	1287.6		+1262.7	+ 10.7
COEFFICIENT	+ .983	+ .008			
SHEAR	2062.0	1123.0	SHEAR REVERSED	2105.4	2105.2
	2059.2	1126.3		2102.8	2107.3
	2059.1	1124.1		2103.6	2107.5
	2059.8	1122.5		2104.1	2108.6
SUM	8240.1	4495.9	SUM	8415.9	8428.6
AVERAGE	2060.0	1124.0	AVERAGE	2104.0	2107.1
DIFFERENCE	+ 44.0	+ 983.1		2060.0	1124.0
CONSTANT	1293.6	1293.6		+44.0	+983.1
COEFFICIENT	+.034	+ .759			
MOMENT	2101.5	2087.1	MOMENT REVERSED	2108.3	1132.3
	2101.8	2086.8		2109.1	1132.6
	2102.3	2088.3		2111.2	1131.9
	2100.0	2085.5		2113.3	1130.5
SUM	8405.6	8347.7	SUM	8441.9	4527.3
AVERAGE	2101.4	2087.4	AVERAGE	2110.5	1131.8
DIFFERENCE	+ 9.1	- 955.6		2101.4	2087.4
CONSTANT	10.858	10.858		+ 9.1	- 955.6
COEFFICIENT	+.838	- 88.009			

RUN #2
BEGGS DEFORMETER
DATA SHEET

RECORDER Perry
OBSERVER Larson

POINT # SD
MICROSCOPE # 108 AL

SHEET # 7
DATE 28 April 1955

PLUG	HORIZONTAL	VERTICAL
NORMAL	2041.5	1901.9
	2036.5	1909.1
	2039.7	1907.8
	2044.7	1905.3
SUM	8162.4	7624.1
AVERAGE	2040.6	1906.0

PLUG	HORIZONTAL	VERTICAL	PLUG	HORIZONTAL	VERTICAL
THRUST	2416.1	2212.3	THRUST REVERSED	1724.3	1596.7
	2418.2	2216.0		1724.1	1591.3
	2415.9	2210.6		1723.5	1595.0
	2416.7	2210.2		1722.1	1596.7
SUM	9666.9	8849.1	SUM	6894.0	6379.7
AVERAGE	2416.7	2212.3	AVERAGE	1723.5	1594.9
DIFFERENCE	−693.2	− 617.4		2416.7	2212.3
CONSTANT	1288.5	1288.5		−693.2	−617.4
COEFFICIENT	−.538	−.479			
SHEAR	2250.3	1984.1	SHEAR REVERSED	1873.2	1873.2
	2251.1	1985.6		1870.9	1870.9
	2251.5	1978.9		1873.1	1873.1
	2255.5	1977.5		1871.2	1871.2
SUM	9008.4	7926.1	SUM	7488.4	7488.4
AVERAGE	2251.9	1981.5	AVERAGE	1872.1	1872.1
DIFFERENCE	− 379.8	− 109.4		2251.9	2251.9
CONSTANT	1289.0	1289.0		− 379.8	− 109.4
COEFFICIENT	−.295	−.085			
MOMENT	1900.9	1938.3	MOMENT REVERSED	2178.4	1872.2
	1901.0	1939.7		2181.7	1877.1
	1901.2	1942.3		2181.9	1872.2
	1903.9	1941.9		2182.2	1870.0
SUM	7607.0	7762.2	SUM	8724.2	7491.5
AVERAGE	1901.8	1940.5	AVERAGE	2181.0	1872.9
DIFFERENCE	+ 279.2	− 67.6		1901.8	1940.5
CONSTANT	10.829	10.829		+ 279.2	− 67.6
COEFFICIENT	+25.783	−6.242			

RUN #2
BEGGS DEFORMETER
DATA SHEET

RECORDER Perry
OBSERVER Larson

POINT # ℄s
MICROSCOPE # 108AL

SHEET # 8
DATE 28 April 1955

PLUG	HORIZONTAL	VERTICAL
NORMAL	1775.7	1242.4
	1773.1	1242.3
	1773.4	1239.5
	1774.6	1240.8
SUM	7096.8	4965.0
AVERAGE	1774.2	1241.2

PLUG	HORIZONTAL	VERTICAL	PLUG	HORIZONTAL	VERTICAL
THRUST	2159.8	1573.0	THRUST REVERSED	1375.3	931.6
	2159.6	1572.1		1377.3	931.5
	2158.9	1569.5		1375.3	936.1
	2156.3	1570.1		1376.7	935.0
SUM	8634.6	6284.7	SUM	4504.6	3734.2
AVERAGE	2158.6	1571.2	AVERAGE	1376.1	933.6
DIFFERENCE	−782.5	−637.6		2158.6	1571.2
CONSTANT	1288.5	1288.5		−782.5	−637.6
COEFFICIENT	−.607	−.495			
SHEAR	2072.3	1341.2	SHEAR REVERSED	1369.9	1220.0
	2071.0	1344.5		1369.2	1222.1
	2073.5	1346.7		1364.4	1222.0
	2076.5	1345.4		1364.0	1219.9
SUM	8293.3	5377.8	SUM	5467.5	4884.0
AVERAGE	2073.3	1344.4	AVERAGE	1366.8	1221.0
DIFFERENCE	−706.4	−123.4		2073.3	1344.4
CONSTANT	1289.0	1289.0		−706.5	−123.4
COEFFICIENT	−.548	−.096			
MOMENT	1352.2	1274.8	MOMENT REVERSED	2099.9	1216.0
	1354.5	1278.3		2102.0	1216.0
	1356.3	1274.8		2101.5	1217.0
	1361.0	1274.9		2101.0	1217.3
SUM	5424.0	5102.8	SUM	8404.4	4866.3
AVERAGE	1356.0	1275.7	AVERAGE	2101.1	1216.6
DIFFERENCE	+745.1	−59.1		1356.0	1275.7
CONSTANT	10.829	10.829		+745.1	−59.1
COEFFICIENT	+68.806	−5.458			

RUN #2
BEGGS DEFORMETER
DATA SHEET

RECORDER Perry
OBSERVER Larson

POINT # PD
MICROSCOPE # 109AL

SHEET # 9
DATE 28 April 1955

PLUG	HORIZONTAL	VERTICAL
NORMAL	1879.3	2203.6
	1877.1	2202.7
	1876.3	2202.9
	1875.8	2202.9
SUM	7508.5	8812.1
AVERAGE	1877.1	2203.0

PLUG	HORIZONTAL	VERTICAL	PLUG	HORIZONTAL	VERTICAL
THRUST	2261.3	1866.1	THRUST REVERSED	1574.5	2508.1
	2258.4	1864.1		1573.2	2504.9
	2265.8	1866.8		1571.0	2506.1
	2261.0	1863.5		1572.5	2501.6
SUM	9046.5	7460.5	SUM	6291.2	10020.7
AVERAGE	2261.6	1865.1	AVERAGE	1572.8	2505.2
DIFFERENCE	-688.8	+640.1		2261.6	1865.1
CONSTANT	1287.6	1287.6		-688.8	+640.1
COEFFICIENT	-.535	+.497			
SHEAR	1729.5	2220.5	SHEAR REVERSED	2096.3	2096.3
	1726.7	2221.8		2093.6	2093.6
	1729.2	2219.6		2094.3	2094.3
	1724.3	2223.9		2094.4	2094.4
SUM	6909.7	8885.8	SUM	8378.6	8378.6
AVERAGE	1727.4	2221.4	AVERAGE	2094.6	2094.6
DIFFERENCE	+367.2	-126.8		1727.4	2221.4
CONSTANT	1293.6	1293.6		+367.2	-126.8
COEFFICIENT	+.284	-.098			
MOMENT	1571.3	2212.1	MOMENT REVERSED	2248.2	2156.5
	1577.7	2214.5		2240.3	2156.1
	1579.5	2211.1		2243.0	2159.1
	1577.0	2215.0		2243.2	2158.0
SUM	6305.5	8852.7	SUM	8974.7	8629.7
AVERAGE	1576.4	2213.2	AVERAGE	2243.7	2157.4
DIFFERENCE	+667.3	-55.8		1576.4	2213.2
CONSTANT	10.858	10.858		+667.3	-55.8
COEFFICIENT	+61.445	-5.138			

RUN #2
BEGGS DEFORMETER
DATA SHEET

RECORDER Perry
OBSERVER Larson

POINT # 8PI
MICROSCOPE # 109 AL

SHEET # 10
DATE 28 April 1955

PLUG	HORIZONTAL	VERTICAL
NORMAL	2100.7	1983.9
	2099.8	1983.5
	2100.9	1983.6
	2101.1	1981.0
SUM	8402.5	7932.0
AVERAGE	2100.6	1983.0

PLUG	HORIZONTAL	VERTICAL	PLUG	HORIZONTAL	VERTICAL
THRUST	2345.4	1690.8	THRUST REVERSED	1864.2	2317.1
	2344.4	1690.3		1861.8	2317.5
	2345.1	1689.8		1865.1	2319.7
	2343.0	1692.2		1865.7	2319.3
SUM	9377.9	6763.1	SUM	7456.8	9273.6
AVERAGE	2344.5	1690.8	AVERAGE	1864.2	2318.4
DIFFERENCE	-480.3	+627.6		2344.5	1690.8
CONSTANT	1287.6	1287.6		-480.3	+627.6
COEFFICIENT	-.373	+.487			
SHEAR	2037.5	2021.5	SHEAR REVERSED	2163.2	1923.3
	2037.8	2020.1		2159.1	1921.5
	2034.5	2022.0		2156.6	1921.3
	2037.0	2023.2		2157.8	1923.1
SUM	8146.8	8086.8	SUM	8636.7	7689.2
AVERAGE	2036.7	2021.7	AVERAGE	2159.2	1922.3
DIFFERENCE	+122.5	-99.4		2036.7	2021.7
CONSTANT	1293.6	1293.6		+122.5	-99.4
COEFFICIENT	+.095	-.077			
MOMENT	1967.5	2035.6	MOMENT REVERSED	2182.4	1984.0
	1964.1	2038.1		2179.3	1985.5
	1960.1	2037.5		2182.0	1987.9
	1962.2	2038.1		2180.5	1986.5
SUM	78539	8149.3	SUM	8724.2	7943.9
AVERAGE	1963.5	2037.3	AVERAGE	2181.0	1986.0
DIFFERENCE	+217.5	-51.3		1963.5	2037.3
CONSTANT	10.858	10.858		+217.5	-51.3
COEFFICIENT	+20.031	-4.734			

RUN #2
BEGGS DEFORMETER
DATA SHEET

RECORDER Perry
OBSERVER Larson

POINT # 4PI
MICROSCOPE # 107AL

SHEET # 11
DATE 28 April 1955

PLUG	HORIZONTAL	VERTICAL
NORMAL	2020.0	2020.0
	2021.5	2021.5
	2020.8	2020.8
	2023.0	2023.0
SUM	8085.3	8085.3
AVERAGE	2021.3	2021.3

PLUG	HORIZONTAL	VERTICAL	PLUG	HORIZONTAL	VERTICAL
THRUST	2034.0	1708.4	THRUST REVERSED	2030.9	2295.3
	2031.5	1705.7		2035.8	2295.1
	2030.0	1707 2		2029.0	2293.1
	2036.0	1707.7		2030.0	2298.3
SUM	8131.5	6829.0	SUM	8125.7	9181.8
AVERAGE	2032.9	1707.2	AVERAGE	2031.4 2032.9 -1.5	2295 4 1707.2 +588.2
DIFFERENCE	-1.5	+588.2			
CONSTANT	1296.7	1296.7			
COEFFICIENT	-.001	+.454			
SHEAR	2029.7	2029.7	SHEAR REVERSED	2030.0	1938.4
	2029.2	2029.2		2039.0	1938.2
	2033.0	2033.0		2034.9	1936.3
	2033.0	2033.0		2037 8	1937.2
SUM	8124.9	8124.9	SUM	8141.7	7756.1
AVERAGE	2031.2	2031.2	AVERAGE	2035.4 2031.2 +4.2	1937.5 2031.2 -93.7
DIFFERENCE	+4.2	-93.7			
CONSTANT	1283.2	1283.2			
COEFFICIENT	+.003	-.073			
MOMENT	2023.4	2052.1	MOMENT REVERSED	2033.5	2011.5
	2021.3	2054.9		2030.0	2010.5
	2028.1	2049.9		2031.2	2014.7
	2023 3	2050.7		2027.9	2013.1
SUM	8096.1	8207.6	SUM	8122.6	8049.8
AVERAGE	2024.0	2051.9	AVERAGE	2030.6 2024.0 +6.6	2012.4 2051.9 -39.5
DIFFERENCE	+6.6	-39.5			
CONSTANT	10.759	10.759			
COEFFICIENT	+.613	-3.671			

RUN #2
BEGGS DEFORMETER
DATA SHEET

RECORDER Perry
OBSERVER Larson

POINT # 2 PI
MICROSCOPE # 1074

SHEET # 12
DATE 28 April 1955

PLUG	HORIZONTAL	VERTICAL
NORMAL	1865.2	1887.5
	1865.5	1884.2
	1867.0	1882.7
	1868.1	1880.4
SUM	7465.8	7534.8
AVERAGE	1866.4	1883.7

PLUG	HORIZONTAL	VERTICAL	PLUG	HORIZONTAL	VERTICAL
THRUST	1878.8	1743.0	THRUST REVERSED	1876.9	2065.2
	1874.8	1743.3		1877.6	2064.9
	1881.1	1747.1		1877.3	2070.8
	1880.5	1745.7		1878.3	2064.8
SUM	7515.2	6979.1	SUM	7510.1	8265.7
AVERAGE	1878.8	1744.8	AVERAGE	1877.5	2066.4
DIFFERENCE	− 1.3	+321.6		1878.8	1744.8
CONSTANT	1296.7	1296.7		− 1.3	+321.6
COEFFICIENT	−.001	+.298			
SHEAR	1872.0	1896.8	SHEAR REVERSED	1870.5	1860.9
	1872.5	1904.6		1870.0	1856.4
	1876.2	1898.6		1870.0	1862.5
	1874.4	1903.7		1873.1	1858.1
SUM	7495.1	7603.7	SUM	7483.6	7437.9
AVERAGE	1873.8	1900.9	AVERAGE	1870.9	1859.5
DIFFERENCE	− 2.9	− 41.4		1873.8	1900.9
CONSTANT	1283.2	1283.2		− 2.9	− 41.4
COEFFICIENT	−.002	−.032			
MOMENT	1857.8	1898.7	MOMENT REVERSED	1858.9	1911.9
	1858.0	1899.8		1864.1	1913.3
	1862.9	1901.5		1866.7	1913.8
	1859.5	1899.8		1866.7	1911.6
SUM	7438.2	7599.8	SUM	7456.4	7650.6
AVERAGE	1859.6	1900.0	AVERAGE	1864.1	1912.6
DIFFERENCE	+ 4.5	+ 12.6		1859.6	1900.0
CONSTANT	10.759	10.759		+ 4.5	+ 12.6
COEFFICIENT	+.418	+1.171			

RUN #2

BEGGS DEFORMETER

DATA SHEET

RECORDER PERRY

OBSERVER LARSON

POINT # 10 PI

MICROSCOPE # 107 AL

SHEET # 13

DATE 29 APRIL 1955

PLUG	HORIZONTAL	VERTICAL
NORMAL		
SUM		
AVERAGE		

PLUG	HORIZONTAL	VERTICAL	PLUG	HORIZONTAL	VERTICAL
THRUST			THRUST REVERSED		
SUM			SUM		
AVERAGE			AVERAGE		
DIFFERENCE					
CONSTANT					
COEFFICIENT					
SHEAR (TO THE LEFT OF THE CUT)	1747.3	1535.3	SHEAR REVERSED	960.0	1380.1
	1746.0	1540.3		968.8	1382.2
	1743.5	1541.2		965.5	1382.2
	1748.9	1537.3		959.5	1385.1
SUM	6985.7	6154.1	SUM	3853.8	5529.6
AVERAGE	1746.4	1538.5	AVERAGE	963.4	1382.4
DIFFERENCE	-783.0	-156.1		1746.4	1538.5
CONSTANT	1283.2	1283.2		-785.0	-156.1
COEFFICIENT	-.610	-.122			
~~MOMENT~~ SHEAR (TO THE RIGHT OF THE CUT)	1534.5	1946.9	SHEAR ~~MOMENT~~ REVERSED	2309.4	2113.2
	1534.2	1949.1		2311.9	2114.8
	1534.4	1948.8		2313.2	2113.0
	1536.1	1946.2		2309.5	2108.7
SUM	6139.2	7791.0	SUM	9244.0	8449.7
AVERAGE	1534.8	1947.8	AVERAGE	2311.0	2112.4
DIFFERENCE	+776.2	+164.6		1534.8	1947.8
CONSTANT	1283.2	1283.2		+776.2	+164.6
COEFFICIENT	+.605	+.128			

RUN #3
BEGGS DEFORMETER
DATA SHEET

RECORDER Perry
OBSERVER Larson

POINT # SD
MICROSCOPE # 107AL

SHEET # 19
DATE 30 April 1955

PLUG	HORIZONTAL	VERTICAL
NORMAL	2193.5	1847.5
	2198.9	1844.2
	2198.4	1841.0
	2194.5	1844.9
SUM	8785.3	7377.6
AVERAGE	2196.3	1844.4

PLUG	HORIZONTAL	VERTICAL	PLUG	HORIZONTAL	VERTICAL
THRUST	2538.0	2139.6	THRUST REVERSED	1844.3	1551.6
	2535.1	2140.8		1843.0	1549.5
	2534.1	2140.3		1844.2	1549.3
	2535.2	2141.5		1843.5	1547.5
SUM	10142.4	8562.2	SUM	7375.0	6197.9
AVERAGE	2535.6	2140.6	AVERAGE	18438 2535.6 -691.8	1549.5 2140.6 -591.1
DIFFERENCE	-691.8	-591.1			
CONSTANT	1296.7	1296.7			
COEFFICIENT	-.534	-.			
SHEAR	2401.9	1925.1	SHEAR REVERSED	2018.5	1796.3
	2400.5	1926.3		2021.7	1795.3
	2402.9	1926.6		2016.7	1795.2
	2402.1	1925.4		2015.5	1796.5
SUM	9607 4	7703.4	SUM	8072.4	7183.3
AVERAGE	2401.8	1925.8	AVERAGE	2018.1 2401.8 -383.7	1795.8 1925.8 -130.0
DIFFERENCE	-383.7	-130.0			
CONSTANT	1283.2	1283.2			
COEFFICIENT	-.299	-.101			
MOMENT	2272.2	1943.5	MOMENT REVERSED	2155.3	1733.9
	2270.2	1944.7		2153.2	1732.3
	2270.3	1943.5		2150.2	1733.5
	2269.7	1943.4		2153.5	1730.3
SUM	9082.4	7775.1	SUM	8612.2	6930.0
AVERAGE	2270.6	1943.8	AVERAGE	2153.0 2270.6 -117.6	1732.5 1943.8 -211.3
DIFFERENCE	-117.6	-211.3			
CONSTANT	10.759	10.759			
COEFFICIENT	-10.930	-19.639			

RUN #3
BEGGS DEFORMETER
DATA SHEET

RECORDER Perry
OBSERVER Larson

POINT # ₵S
MICROSCOPE # 107 AL

SHEET # 15
DATE 30 April 1955

PLUG	HORIZONTAL	VERTICAL
NORMAL	1980.3	1855.1
	1977.3	1850.2
	1978.5	1853.2
	1979.6	1850.4
SUM	7915.7	7408.9
AVERAGE	1978.9	1852.2

PLUG	HORIZONTAL	VERTICAL	PLUG	HORIZONTAL	VERTICAL
THRUST	2397.7	2175.2	THRUST REVERSED	1611.9	1540.6
	2399.1	2173.7		1609.0	1542.1
	2396.9	2168.3		1612.1	1544.0
	2393.8	2169.5		1615.0	1543.4
SUM	9587.5	8686.7	SUM	6448.0	6170.1
AVERAGE	2396.9	2171.7	AVERAGE	1612.0	1542.5
DIFFERENCE	- 784.9	-629.2		2396.9	2171.7
CONSTANT	1296.7	1296.7		-784.9	-629.2
COEFFICIENT	-.605	-.485			
SHEAR	2338.7	1935.0	SHEAR REVERSED	1731.0	1791.5
	2338.1	1933.9		1724.8	1788.3
	2338.2	1933.1		1726.3	1784.3
	2334.5	1938.9		1727.5	1786.9
SUM	9349.5	7740.9	SUM	6909.6	7151.0
AVERAGE	2337.4	1935.2	AVERAGE	1727.4	1787.8
DIFFERENCE	-610.0	-147.4		23374	1935.2
CONSTANT	1283.2	1283.2		- 610.0	-147.4
COEFFICIENT	-.475	-.115			
MOMENT	1989.6	1971.5	MOMENT REVERSED	2017.0	1720.2
	1990.8	1971.5		2020.1	1719.8
	1991.8	1967.5		2018.2	1719.4
	1990.1	1965.1		2020.2	1718.8
SUM	7962.3	7875.6	SUM	8075.5	6878.2
AVERAGE	1990.6	1968.9	AVERAGE	2018.9	1719.6
DIFFERENCE	+ 28.3	- 249.3		1990.6	1968.9
CONSTANT	10.759	10.759		+ 28.3	-249.3
COEFFICIENT	+ 2.630	- 23.171			

RUN #3

BEGGS DEFORMETER

DATA SHEET

RECORDER Perry
OBSERVER Larson

POINT # PD
MICROSCOPE # 108AL

SHEET # 16
DATE 30 April 1955

PLUG	HORIZONTAL	VERTICAL
NORMAL	1772.5	1996.0
	1775.0	1996.1
	1773.0	1995.4
	1771.1	1993.4
SUM	7091.6	7980.9
AVERAGE	1772.9	1995.2

PLUG	HORIZONTAL	VERTICAL	PLUG	HORIZONTAL	VERTICAL
THRUST	2079.4	2289.3	THRUST REVERSED	1394.5	1674.5
	2081.5	2288.8		1394.7	1670.3
	2078.4	2287.0		1396.9	1676.5
	2078.8	2286.0		1397.5	1672.8
SUM	8318.1	9151.1	SUM	5583.1	6694.1
AVERAGE	2079.5	2287.8	AVERAGE	1395.8	1673.5
DIFFERENCE	−683.7	−614.3		−2079.5	2287.8
CONSTANT	1288.5	1288.5		−683.7	−619.3
COEFFICIENT	−.531	−.477			
SHEAR	2200.3	2067.0	SHEAR REVERSED	1342.5	1925.2
	2200.9	2067.5		1341.3	1928.9
	2199.9	2064.4		1339.1	1931.9
	2198.4	2067.3		1345.1	1927.5
SUM	8799.5	8266.2	SUM	5368.0	7713.5
AVERAGE	2199.9	2066.6	AVERAGE	1342.0	1928.4
DIFFERENCE	−857.9	−138.2		2199.9	2066.6
CONSTANT	1289.0	1289.0		−857.9	−138.2
COEFFICIENT	−.666	−.107			
MOMENT	1533.1	2071.5	MOMENT REVERSED	2030.9	1868.9
	1529.0	2076.2		2035.0	1868.2
	1527.9	2079.3		2033.3	1866.3
	1535.2	2077.3		2029.0	1867.1
SUM	6125.2	8304.3	SUM	8128.2	7470.5
AVERAGE	1531.3	2076.1	AVERAGE	2032.0	1867.6
DIFFERENCE	+500.7	−208.5		1531.3	2076.1
CONSTANT	10.829	10.829		+500.7	−208.5
COEFFICIENT	+46.237	−19.254			

RUN #3
BEGGS DEFORMETER
DATA SHEET

RECORDER Perry
OBSERVER Larson

POINT # 9PI
MICROSCOPE # 10891

SHEET # 17
DATE 30 April 1955

PLUG	HORIZONTAL	VERTICAL
NORMAL		
SUM		
AVERAGE		

PLUG	HORIZONTAL	VERTICAL	PLUG	HORIZONTAL	VERTICAL
THRUST			THRUST REVERSED		
SUM			SUM		
AVERAGE			AVERAGE		
DIFFERENCE					
CONSTANT					
COEFFICIENT					
SHEAR (TO THE LEFT OF THE CUT)	2027.3	2332.1	SHEAR REVERSED	1059.5	2188.5
	2024.0	2336.7		1065.5	2184.0
	2027 2	2335 8		1061 3	2188.0
	2026 3	2334.1		1062 2	2184 8
SUM	8104.8	9338.7	SUM	4248 5	8745.3
AVERAGE	2026.2	2334.7	AVERAGE	1062.1	2186.3
DIFFERENCE	-964 1	-148.4		2026.2	2334 7
CONSTANT	1289.0	1289.0		-964.1	-148 4
COEFFICIENT	-.748	-.115			
~~MOMENT~~ SHEAR (TO THE RIGHT OF THE CUT)	1586.8	1289.1	SHEAR ~~MOMENT~~ REVERSED	1840.4	1174.2
	1589.5	1289 0		1843.4	1173 9
	1586.4	1290.5		1839.3	1172.0
	1588.1	1286.6		1842.3	1173.2
SUM	6350 8	5155.2	SUM	7365 4	4693 3
AVERAGE	1587.7	1288.8	AVERAGE	1841.4	1173.3
DIFFERENCE	+253 7	-115.5		1587 7	1288.8
CONSTANT	1289.0	1289.0		+253.7	-115.5
COEFFICIENT	+.197	-.090			

RUN #3
BEGGS DEFORMETER
DATA SHEET

RECORDER Perry
OBSERVER Larson

POINT # 8PI
MICROSCOPE # 108AL

SHEET # 18
DATE 30April1955

PLUG	HORIZONTAL	VERTICAL
NORMAL	2007.9	2209.9
	2008.3	2211.1
	2008.2	2213.1
	2008.9	2212.3
SUM	8033.3	8846.4
AVERAGE	2008.3	2211.6

PLUG	HORIZONTAL	VERTICAL	PLUG	HORIZONTAL	VERTICAL
THRUST	2261.0	1897.8	THRUST REVERSED	1784.8	2528.2
	2259.6	1898.7		1783.4	2529.1
	2261.8	1895.5		1784.9	2530.1
	2263.1	1896.4		1784.9	2530.8
SUM	9045.5	7588.4	SUM	7138.0	10118.2
AVERAGE	2261.4	1897.1	AVERAGE	1784.5 2261.4 −476.9	2529.6 1897.1 +632.5
DIFFERENCE	−476.9	+632.5			
CONSTANT	1288.5	1288.5			
COEFFICIENT	−.370	+.491			
SHEAR	1948.2	2260.0	SHEAR REVERSED	2132.1	2132.1
	1947.6	2260.3		2134.5	2134.5
	1949.5	2261.5		2132.3	2132.3
	1947.3	2258.5		2133.0	2133.0
SUM	7792.6	9040.3	SUM	8531.9	8531.9
AVERAGE	1948.2	2260.1	AVERAGE	2133.0 1948.2 +184.8	2133.0 2260.1 −127.1
DIFFERENCE	+184.8	−127.1			
CONSTANT	1289.0	1289.0			
COEFFICIENT	+.193	−.099			
MOMENT	1834.8	2296.9	MOMENT REVERSED	2235.0	2093.3
	1834.8	2298.0		2234.5	2091.5
	1838.0	2298.0		2229.8	2090.3
	1833.5	2296.0		2231.5	2091.2
SUM	7341.1	9188.9	SUM	8930.8	8366.3
AVERAGE	1835.3	2297.2	AVERAGE	2232.7 1835.3 +397.4	2091.6 2297.2 −205.6
DIFFERENCE	+397.4	−205.6			
CONSTANT	10.829	10.829			
COEFFICIENT	+36.698	−18.986			

RUN #3

BEGGS DEFORMETER

DATA SHEET

RECORDER Perry

OBSERVER Larsen

POINT # 4PI

MICROSCOPE # 109AL

SHEET # 19

DATE 30 April 1955

PLUG	HORIZONTAL	VERTICAL
NORMAL	1910.5	1955.1
	1910.5	1955.0
	1912.5	1955.5
	1911.5	1955.4
SUM	7645.0	7821.0
AVERAGE	1911.2	1955.2

PLUG	HORIZONTAL	VERTICAL	PLUG	HORIZONTAL	VERTICAL
THRUST	1912.6	1654.7	THRUST REVERSED	1928.7	2258.0
	1915.6	1656.7		1926.7	2257.7
	1912.5	1653.0		1928.9	2259.3
	1915.4	1656.4		1929.3	2261.0
SUM	7656.1	6620.8	SUM	7713.6	9036.0
AVERAGE	1914.0	1655.2	AVERAGE	19284	2259.0
DIFFERENCE	+14.4	+603.8		1914.0	1655.2
CONSTANT	1287.6	1287.6		+14.4	+603.8
COEFFICIENT	+.011	+.469			
SHEAR	1924.8	2004.7	SHEAR REVERSED	1930.2	1897.5
	1926.2	2004.3		1929.2	1893.4
	1926.5	2007.9		1929.1	1894.1
	1926.8	2008.0		1930.1	1898.2
SUM	7704.3	8024.9	SUM	7718.6	7583.2
AVERAGE	1926.1	2006.2	AVERAGE	1929.6	1895.8
DIFFERENCE	+3.5	−110.4		1926.1	2006.2
CONSTANT	1293.6	1293.6		+3.5	−110.4
COEFFICIENT	+.003	−.085			
MOMENT	1926.2	2033.5	MOMENT REVERSED	1924.1	1856.6
	1926.5	2029.9		1925.8	1858.5
	1930.2	2030.3		1924.8	1860.0
	1926.0	2033.3		1924.8	1856.9
SUM	7708.9	8127.0	SUM	7699.5	7432.0
AVERAGE	1927.2	2031.8	AVERAGE	1924.9	1858.0
DIFFERENCE	− 2.3	−173.8		1927.2	2031.8
CONSTANT	10.858	10.858		− 2.3	−173.8
COEFFICIENT	−.212	−16.007			

RUN #3
BEGGS DEFORMETER
DATA SHEET

RECORDER Perry
OBSERVER Larson

POINT # 2PI
MICROSCOPE # 109AL

SHEET # 20
DATE 30 April 1955

PLUG	HORIZONTAL	VERTICAL
NORMAL	1937.3	1798.5
	1936.2	1798.4
	1941.1	1799.6
	1940.9	1798.2
SUM	7755.5	7194.7
AVERAGE	1938.9	1798.7

PLUG	HORIZONTAL	VERTICAL	PLUG	HORIZONTAL	VERTICAL
THRUST	1945.5	1641.0	THRUST REVERSED	1950.0	1960.4
	1944.5	1636.5		1947.3	1963.0
	1946.9	1642.4		1949.5	1960.5
	1944.9	1640.3		1947.5	1961.5
SUM	7781.8	6560.2	SUM	7794.3	7845.4
AVERAGE	1945.4	1640.0	AVERAGE	1948.6 1945.4 + 3.2	1961.4 1640.0 +321.4
DIFFERENCE	+ 3.2	+ 321.4			
CONSTANT	1287.6	1287.6			
COEFFICIENT	+.002	+.250			
SHEAR	1941.4	1814.0	SHEAR REVERSED	1949.6	1767.8
	1942.5	1815.2		1947.1	1765.1
	1940.5	1813.4		1948.5	1764.1
	1941.0	1814.5		1947.1	1767.4
SUM	7765.4	7257.1	SUM	7792.3	7064.4
AVERAGE	1941.4	1814.3	AVERAGE	1948.1 1941.4 + 6.7	1766.1 1814.3 - 48.2
DIFFERENCE	+ 6.7	- 48.2			
CONSTANT	1293.6	1293.6			
COEFFICIENT	+.005	-.037			
MOMENT	1944.8	1825.8	MOMENT REVERSED	1941.9	1754.0
	1944.5	1826.1		1942.3	1752.5
	1945.0	1824.1		1943.0	1755.5
	1944.8	1827.3		1941.0	1751.0
SUM	7779.1	7303.3	SUM	7768.2	7013.0
AVERAGE	1944.8	1825.8	AVERAGE	1942.0 1944.8 - 2.8	1753.2 1825.8 - 72.6
DIFFERENCE	- 2.8	- 72.6			
CONSTANT	10.858	10.858			
COEFFICIENT	-.258	-6.686			

RUN #4
BEGGS DEFORMETER
DATA SHEET

RECORDER Perry
OBSERVER Larson

POINT # 50
MICROSCOPE # 108AL

SHEET # 21
DATE 2 May 1955

PLUG	HORIZONTAL	VERTICAL
NORMAL	1025.5	1006.1
	1025.5	1003.3
	1027.4	1002.5
	1029.5	1002.5
SUM	4107.9	4014.4
AVERAGE	1027.0	1003.6

PLUG	HORIZONTAL	VERTICAL	PLUG	HORIZONTAL	VERTICAL
THRUST	1380.3	1286.2	THRUST REVERSED	664.7	693.0
	1380.1	1285.1		668.5	695.1
	1381.0	1286.0		663.5	696.2
	1380.2	1282.3		669.2	691.2
SUM	5521.6	5139.6	SUM	2671.9	2775.5
AVERAGE	1380.4	1284.9	AVERAGE	668.0	693.9
DIFFERENCE	-712.4	-591.0		1380.4	1284.9
CONSTANT	1288.5	1288.5		-712.4	-591.0
COEFFICIENT	-.553	-.459			
SHEAR	1202.5	1046.5	SHEAR REVERSED	860.4	952.7
	1204.4	1043.4		862.5	952.5
	1204.3	1046.1		863.0	952.1
	1206.8	1047.3		862.3	952.4
SUM	4818.0	4183.3	SUM	3448.2	3809.7
AVERAGE	1204.5	1045.8	AVERAGE	862.0	952.4
DIFFERENCE	-342.5	-93.4		1204.5	1045.8
CONSTANT	1289.0	1289.0		-342.5	-93.4
COEFFICIENT	-.266	-.072			
MOMENT	1279.9	1164.1	MOMENT REVERSED	789.2	833.7
	1283.3	1163.5		785.2	828.3
	1284.5	1161.6		791.5	836.0
	1285.3	1159.7		788.9	831.2
SUM	5133.0	4648.9	SUM	3154.8	3329.2
AVERAGE	1283.2	1162.2	AVERAGE	788.7	832.3
DIFFERENCE	-494.5	-329.9		1283.2	1162.2
CONSTANT	10.829	10.829		-494.5	-329.9
COEFFICIENT	-45.664	-30.474			

RUN #4
BEGGS DEFORMETER
DATA SHEET

RECORDER Perry
OBSERVER Larson
POINT # ¢S
MICROSCOPE # 108AL
SHEET # 22
DATE 7 May 1955

PLUG	HORIZONTAL	VERTICAL
NORMAL	1753.0	1880.4
	1754.5	1878.2
	1755.8	1877.8
	1756.3	1880.1
SUM	7019.6	7516.5
AVERAGE	1754.9	1879.1

PLUG	HORIZONTAL	VERTICAL	PLUG	HORIZONTAL	VERTICAL
THRUST	2170.3	2189.8	THRUST REVERSED	1391.3	1568.8
	2173.2	2189.9		1392.2	1565.4
	2170.8	2187.7		1390.9	1566.2
	2172.3	2184.9		1395.2	1566.3
SUM	8686.6	8752.3	SUM	5569.6	6266.7
AVERAGE	2171.6	2188.1	AVERAGE	1392.4 2171.6 -779.2	1566.7 2188.1 -621.4
DIFFERENCE	-779.2	-621.4			
CONSTANT	1288.5	1288.5			
COEFFICIENT	-.605	-.482			
SHEAR	2112.3	1956.0	SHEAR REVERSED	1549.3	1842.2
	2110.8	1957.6		1550.5	1844.1
	2111.9	1957.2		1551.9	1842.6
	2109.9	1951.5		1548.2	1840.5
SUM	8444.9	7822.3	SUM	6199.9	7369.4
AVERAGE	2111.2	1955.6	AVERAGE	1550.0 2111.2 -561.2	1842.4 1955.6 -113.2
DIFFERENCE	-561.2	-113.2			
CONSTANT	1289.0	1289.0			
COEFFICIENT	-.435	-.088			
MOMENT	2081.1	2059.0	MOMENT REVERSED	1543.3	1724.2
	2076.1	2057.5		1544.7	1721.9
	2079.6	2059.0		1545.6	1722.8
	2078.3	2057.0		1545.1	1721.1
SUM	8315.1	8232.5	SUM	6178.7	6890.0
AVERAGE	2078.8	2058.1	AVERAGE	1544.7 2078.8 -534.1	1722.5 2058.1 -335.6
DIFFERENCE	-534.1	-335.6			
CONSTANT	10.229	10.229			
COEFFICIENT	-49.321	-30.991			

RUN #4

BEGGS DEFORMETER

DATA SHEET

RECORDER Perry
OBSERVER Larson

POINT # PD
MICROSCOPE # 109AL

SHEET # 23
DATE 2 May 1955

PLUG	HORIZONTAL	VERTICAL
NORMAL	1961.5	1874.0
	1955.8	1870.6
	1961.1	1873.2
	1962.1	1874.5
SUM	7840.5	7492.3
AVERAGE	1960.1	1873.1

PLUG	HORIZONTAL	VERTICAL	PLUG	HORIZONTAL	VERTICAL
THRUST	2316.5	1157.0	THRUST REVERSED	1592.3	1545.4
	2318.4	1159.5		1592.8	1545.2
	2316.8	1160.3		1590.5	1545.6
	2311.1	1156.6		1591.1	1547.8
SUM	9262.8	4633.4	SUM	6366.7	6184.0
AVERAGE	2315.7	1158.4	AVERAGE	1591.7	1546.0
DIFFERENCE	-724.0	387.6		2315.7	1158.4
CONSTANT	1287.6	1287.6		-724.0	387.6
COEFFICIENT	-.562	.301			
SHEAR	2385.1	1911.1	SHEAR REVERSED	1542.3	1801.6
	2384.0	1912.6		1543.4	1804.2
	2382.2	1912.4		1539.4	1803.4
	2384.1	1913.0		1541.0	1802.6
SUM	9535.4	7649.1	SUM	6166.1	7211.8
AVERAGE	2383.8	1912.3	AVERAGE	1541.5	1803.0
DIFFERENCE	-842.3	-109.3		2383.8	1912.3
CONSTANT	1293.6	1293.6		-842.3	-109.3
COEFFICIENT	-.651	-.084			
MOMENT	2152.1	2022.8	MOMENT REVERSED	1803.5	1681.8
	2149.1	2025.5		1796.2	1679.8
	2147.0	2023.1		1792.9	1679.4
	2146.6	2026.3		1792.8	1679.9
SUM	8594.8	8097.7	SUM	7185.4	6720.9
AVERAGE	2148.7	2024.4	AVERAGE	1796.4	1680.2
DIFFERENCE	-352.3	-344.2		2148.7	2024.4
CONSTANT	10.858	10.858		-352.3	-344.2
COEFFICIENT	-32.446	-31.700			

RUN #4
BEGGS DEFORMETER
DATA SHEET

RECORDER Perry
OBSERVER Larson

POINT # 8PI
MICROSCOPE # 109AL

SHEET # 24
DATE 2May1955

PLUG	HORIZONTAL	VERTICAL
NORMAL	2170.2	2190.2
	2165.7	2183.2
	2164.8	2188.3
	2168.5	2187.8
SUM	8669.2	8749.5
AVERAGE	2167.3	2187.4

PLUG	HORIZONTAL	VERTICAL	PLUG	HORIZONTAL	VERTICAL
THRUST	2410.9	2499.2	THRUST REVERSED	1953.6	1869.7
	2408.4	2500.3		1950.5	1872.5
	2408.3	2499.1		1949.1	1871.1
	2408.5	2501.0		1947.5	1872.5
SUM	9626.1	9999.6	SUM	7800.7	7485.8
AVERAGE	2406.5	2499.9	AVERAGE	1950.2 2406.5 -456.3	1871.4 2499.9 -628.5
DIFFERENCE	-456.3	-628.5			
CONSTANT	1287.6	1287.6			
COEFFICIENT	-.354	-.488			
SHEAR	2755.6	2292.2	SHEAR REVERSED	1666.6	2137.2
	2757.1	2292.3		1664.5	2135.9
	2751.9	2296.1		1666.6	2136.9
	2750.5	2296.5		1670.1	2136.4
SUM	11015.1	9177.1	SUM	6667.8	8546.4
AVERAGE	2753.8	2294.3	AVERAGE	1667.0 2753.8 -10868	2136.6 2294 3 -157.7
DIFFERENCE	-1086.8	-157.7			
CONSTANT	1293.6	1293.6			
COEFFICIENT	-.840	-.122			
MOMENT	2093.3	2369.4	MOMENT REVERSED	2303.2	2029.6
	2095.5	2368.3		2302.3	2031.7
	2093.6	2366.8		2306.6	2031.9
	2095.5	2370.2		2302.5	2031.5
SUM	8377 9	9474.7	SUM	9219.6	8124.7
AVERAGE	2094.5	2368.7	AVERAGE	2303.6 2094.5 + 209.1	2031.2 2368.7 -337.5
DIFFERENCE	+209.1	-337.5			
CONSTANT	10.858	10.858			
COEFFICIENT	+19.258	-31.083			

RUN #4
BEGGS DEFORMETER
DATA SHEET

RECORDER Perry
OBSERVER Larson

POINT # 7PI
MICROSCOPE # 107AL

SHEET # 25
DATE 2 May 1955

PLUG	HORIZONTAL	VERTICAL
NORMAL		
SUM		
AVERAGE		

PLUG	HORIZONTAL	VERTICAL	PLUG	HORIZONTAL	VERTICAL
THRUST			THRUST REVERSED		
SUM			SUM		
AVERAGE			AVERAGE		
DIFFERENCE					
CONSTANT					
COEFFICIENT					
SHEAR (TO THE LEFT OF THE CUT)	2848.4	1946.8	SHEAR REVERSED	1753.0	1852.8
	2847.4	1942.9		1749.5	1850.8
	2843.6	1947.9		1746.3	1850.1
	2840.5	1943.6		1744.3	1850.5
SUM	11379.9	7781.2	SUM	6993.1	7404.2
AVERAGE	2845.0	1945.3	AVERAGE	1748.3	1851.0
DIFFERENCE	-1096.7	- 94.3		2845.0	1995.3
CONSTANT	1283.2	1283.2		-1096.7	- 94.3
COEFFICIENT	- .855	-.073			
~~MOMENT~~ SHEAR (TO THE RIGHT OF THE CUT)	1630.5	2370.2	SHEAR ~~MOMENT~~ REVERSED	1767.3	2199.0
	1630.5	2364.2		1771.3	2197.5
	1630.7	2372.6		1770.2	2202.5
	1630.4	2366.5		1766.9	2202.0
SUM	6522.1	9473.5	SUM	7075.7	8801.0
AVERAGE	1630.5	2368.4	AVERAGE	1768.9	2200.2
DIFFERENCE	+138.4	-168.2		1630.5	2368.4
CONSTANT	1283.2	1283.2		+138.4	-168.2
COEFFICIENT	+.108	-.131			

RUN #4
BEGGS DEFORMETER
DATA SHEET

RECORDER Perry
OBSERVER Larsen

POINT # 4PI
MICROSCOPE # 107AL

SHEET # 26
DATE 2 May 1955

PLUG	HORIZONTAL	VERTICAL
NORMAL	2313.6	2017.8
	2314.9	2020.6
	2315.5	2021.2
	2313.8	2020.1
SUM	9257.8	8079.7
AVERAGE	2314.4	2019.9

PLUG	HORIZONTAL	VERTICAL	PLUG	HORIZONTAL	VERTICAL
THRUST	2321.1	1700.1	THRUST REVERSED	2313.3	2296.7
	2319.4	1700.3		2310.5	2297.5
	2319.8	1698.4		2312.2	2297.5
	2319.9	1701.8		2312.2	2297.9
SUM	9280.2	6800.6	SUM	9248.2	9189.6
AVERAGE	2320.0	1700.2	AVERAGE	2312.0 2320.0 − 8.0	2297.4 1700.2 + 597.2
DIFFERENCE	− 8.0	+ 597.2			
CONSTANT	1296.7	1296.7			
COEFFICIENT	− .006	+ .461			
SHEAR	2326.1	2064.5	SHEAR REVERSED	2327.7	1930.0
	2323.1	2066.2		2328.8	1926.1
	2325.9	2066.5		2328.5	1927.9
	2323.8	2064.8		2325.8	1929.0
SUM	9298.9	8262.0	SUM	9310.8	7713.0
AVERAGE	2324.7	2065.5	AVERAGE	2327.7 2324.7 + 3.0	1928.2 2065.5 − 137.3
DIFFERENCE	+ 3.0	− 137.3			
CONSTANT	1283.2	1283.2			
COEFFICIENT	+ .002	− .107			
MOMENT	2325.1	2154.9	MOMENT REVERSED	2331.7	1867.0
	2325.5	2156.5		2332.7	1861.5
	2325.4	2157.2		2333.9	1866.8
	2326.3	2159.3		2332.5	1867.0
SUM	9302.3	8627.4	SUM	9330.8	7462.3
AVERAGE	2325.6	2156.8	AVERAGE	2332.7 2325.6 + 7.1	1865.6 2156.8 − 291.2
DIFFERENCE	+ 7.1	− 291.2			
CONSTANT	10.759	10.759			
COEFFICIENT	+ .660	− 27.065			

RUN #4
BEGGS DEFORMETER
DATA SHEET

RECORDER Perry
OBSERVER Larson

POINT # 2PI
MICROSCOPE # 107AL

SHEET # 27
DATE 2 May 1955

PLUG	HORIZONTAL	VERTICAL
NORMAL	2086.6	2177.7
	2088.6	2176.9
	2084.0	2181.2
	2088.0	2178.8
SUM	8347.2	8714.6
AVERAGE	2086.8	2178.6

PLUG	HORIZONTAL	VERTICAL	PLUG	HORIZONTAL	VERTICAL
THRUST	2085.2	1991.3	THRUST REVERSED	2086.4	2343.2
	2082.5	1992.2		2088.4	2345.2
	2083.2	1993.6		2087.1	2343.2
	2083.5	1992.0		2088.3	2347.0
SUM	8334.4	7969.1	SUM	8350.2	9378.6
AVERAGE	2083.6	1992.3	AVERAGE	2087.6	2344.6
DIFFERENCE	+ 4.0	+ 352.3		2083.6	1992.3
CONSTANT	1296.7	1296.7		+ 4.0	+ 352.3
COEFFICIENT	+.003	+.272			
SHEAR	2066.8	2179.6	SHEAR REVERSED	2081.6	2126.2
	2067.6	2174.5		2082.6	2125.5
	2069.2	2177.7		2081.0	2126.5
	2071.1	2173.5		2083.3	2128.2
SUM	8274.7	8705.3	SUM	8328.5	8506.4
AVERAGE	2068.7	2176.3	AVERAGE	2082.1	2126.6
DIFFERENCE	+ 13.4	− 49.7		2068.7	2176.3
CONSTANT	1283.2	1283.2		+ 13.4	− 49.7
COEFFICIENT	+.010	−.039			
MOMENT	2082.4	2212.4	MOMENT REVERSED	2085.7	2099.9
	2080.5	2213.8		2085.3	2099.9
	2081.2	2212.3		2086.3	2099.3
	2083.1	2211.5		2085.9	2099.0
SUM	8327.2	8850.0	SUM	8343.2	8398.1
AVERAGE	2081.8	2212.5	AVERAGE	2085.8	2099.5
DIFFERENCE	+ 4.0	− 113.0		2081.8	2212.5
CONSTANT	10.759	10.759		+ 4.0	− 113.0
COEFFICIENT	+.372	−10.503			

RUN #5
BEGGS DEFORMETER
DATA SHEET

RECORDER Perry
OBSERVER Larson

POINT # SD
MICROSCOPE # 107 AL

SHEET # 27
DATE 16 MAY

PLUG	HORIZONTAL	VERTICAL
NORMAL	1615.9	1394.0
	1619.2	1393.5
	1618.0	1390.5
	1615.2	1393.3
SUM	6468.3	5571.3
AVERAGE	1617.1	1392.8

PLUG	HORIZONTAL	VERTICAL	PLUG	HORIZONTAL	VERTICAL
THRUST	1986.8	1082.0	THRUST REVERSED	1293.5	1740.4
	1990.4	1081.3		1295.0	1738.5
	1987.1	1083.0		1293.2	1741.1
	1991.1	1078.8		1294.4	1738.7
SUM	7955.4	4325.1	SUM	5176.1	6958.7
AVERAGE	1988.8	1081.3	AVERAGE	1294.0	1739.7
DIFFERENCE	−694.8	+658.4		1988.8	1081.3
CONSTANT	1296.7	1296.7		−694.8	658.4
COEFFICIENT	−.536	+.508			
SHEAR	1211.0	1480.1	SHEAR REVERSED	2069.5	1346.0
	1209.5	1483.2		2067.8	1345.6
	1209.5	1479.1		2069.5	1345.8
	1211.5	1478.3		2072.1	1343.2
SUM	4841.5	5920.7	SUM	8278.9	5380.6
AVERAGE	1210.4	1480.2	AVERAGE	2069.7	1345.1
DIFFERENCE	+859.3	−135.1		1210.4	1480.2
CONSTANT	1288.2	1288.2		859.3	−135.1
COEFFICIENT	+.670	−.105			
MOMENT	1176.9	1379.9	MOMENT REVERSED	2053.1	1566.9
	1179.8	1384.5		2051.8	1569.1
	1173.0	1376.6		2057.2	1574.8
	1179.2	1386.3		2054.0	1570.0
SUM	4708.9	5527.3	SUM	8216.1	6282.8
AVERAGE	1177.2	1381.8	AVERAGE	2054.0	1570.7
DIFFERENCE	+876.8	+188.9		1177.2	1381.8
CONSTANT	10.759	10.759		876.8	188.9
COEFFICIENT	+81.495	+17.557			

RUN #5

BEGGS DEFORMETER

DATA SHEET

RECORDER Perry
OBSERVER Larson

POINT # ℄S
MICROSCOPE # 107 AL

SHEET # 29
DATE 16 MAY

PLUG	HORIZONTAL	VERTICAL
NORMAL	2000.0	2043.0
	2000.0	2043.1
	2004.6	2044.1
	2003.4	2041.5
SUM	8008.0	8171.7
AVERAGE	2002.0	2042.9

PLUG	HORIZONTAL	VERTICAL	PLUG	HORIZONTAL	VERTICAL
THRUST	2412.0	1699.4	THRUST REVERSED	1685.1	2419.2
	2408.4	1698.2		1686.1	2418.4
	2408.9	1700.9		1686.5	2416.2
	2410.1	1701.1		1682.1	2415.2
SUM	9639.4	6799.6	SUM	6739.8	9669.0
AVERAGE	2409.8	1699.9	AVERAGE	1685.0	2417.2
DIFFERENCE	-724.8	+717.3		2409.8	1699.9
CONSTANT	1296.7	1296.7		-724.8	717.3
COEFFICIENT	-.559	+.553			
SHEAR	1744.8	2128.6	SHEAR REVERSED	2405.5	1961.1
	1746.5	2130.4		2402.8	1962.7
	1740.0	2128.8		2404.2	1963.3
	1741.0	2129.6		2403.9	1962.8
SUM	6972.3	8517.4	SUM	9616.4	7849.9
AVERAGE	1743.1	2129.4	AVERAGE	2404.1	1962.5
DIFFERENCE	+661.0	-166.9		1743.1	2129.4
CONSTANT	1283.2	1283.2		661.0	-166.9
COEFFICIENT	+.515	-.130			
MOMENT	1886.3	1976.7	MOMENT REVERSED	2269.8	2134.5
	1883.9	1976.6		2268.9	2136.9
	1881.9	1976.0		2271.8	2136.1
	1884.8	1976.2		2271.8	2138.0
SUM	7536.9	7905.5	SUM	9082.3	8545.5
AVERAGE	1884.2	1976.4	AVERAGE	2270.6	2136.4
DIFFERENCE	+386.4	+160.0		1884.2	1976.4
CONSTANT	10.759	10.759		386.4	160.0
COEFFICIENT	+35.914	+14.871			

RUN #5

BEGGS DEFORMETER

DATA SHEET

RECORDER Perry

OBSERVER LARSON

POINT # PD

MICROSCOPE # 108 AL

SHEET # 30

DATE 16 MAY

PLUG	HORIZONTAL	VERTICAL
NORMAL	1911.4	1911.4
	1911.5	1911.5
	1913.2	1913.2
	1910.0	1910.0
SUM	7646.1	7646.1
AVERAGE	1911.5	1911.5

PLUG	HORIZONTAL	VERTICAL	PLUG	HORIZONTAL	VERTICAL
THRUST	2260.4	1597.0	THRUST REVERSED	1561.3	2252.3
	2264.5	1601.3		1561.4	2253.2
	2262.2	1599.2		1561.5	2253.2
	2264.1	1601.0		1561.4	2253.8
SUM	9051.2	6398.5	SUM	6245.6	9012.5
AVERAGE	2262.8	1599.6	AVERAGE	1561.4 2262.8 -701.4	2253.1 1599.6 653.5
DIFFERENCE	-701.4	+653.5			
CONSTANT	1288.5	1288.5			
COEFFICIENT	-.544	+.507			
SHEAR	1719.6	1998.2	SHEAR REVERSED	2145.4	1858.8
	1720.2	1999.0		2146.0	1858.8
	1722.3	1999.1		2146.5	1859.5
	1719.0	1998.9		2148.3	1858.7
SUM	6881.1	7995.2	SUM	8586.2	7435.8
AVERAGE	1720.3	1998.8	AVERAGE	2146.5 1720.3 426.2	1858.9 1998.8 -139.9
DIFFERENCE	+426.2	-139.9			
CONSTANT	1289.0	1289.0			
COEFFICIENT	+.331	-.109			
MOMENT	1917.6	1845.2	MOMENT REVERSED	1956.2	2016.0
	1914.6	1848.0		1959.3	2015.8
	1916.1	1846.5		1960.8	2018.1
	1913.2	1844.3		1959.8	2016.3
SUM	7661.5	7384.0	SUM	7836.1	8066.2
AVERAGE	1915.4	1846.0	AVERAGE	1959.0 1915.4 43.6	2016.5 1846.0 170.5
DIFFERENCE	+43.6	+170.5			
CONSTANT	10.829	10.829			
COEFFICIENT	+4.026	+15.745			

RUN #5
BEGGS DEFORMETER
DATA SHEET

RECORDER Perry
OBSERVER Larson

POINT # 5PI
MICROSCOPE # 108AL

SHEET # 31
DATE 16 MAY

PLUG	HORIZONTAL	VERTICAL
NORMAL	1975.4	1921.5
	1975.6	1921.4
	1974.3	1920.4
	1973.3	1920.3
SUM	7898.6	7683.6
AVERAGE	1974.6	1920.9

PLUG	HORIZONTAL	VERTICAL	PLUG	HORIZONTAL	VERTICAL
THRUST	2202.2	1590.1	THRUST REVERSED	1739.3	2269.3
	2202.6	1592.0		1742.3	2266.5
	2200.1	1593.1		1743.1	2268.1
	2200.5	1590.2		1743.2	2267.7
SUM	8805.4	6365.4	SUM	6967.9	9071.6
AVERAGE	2201.4	1591.4	AVERAGE	1742.0	2267.9
DIFFERENCE	-459.4	+676.5		2201.4	1591.4
CONSTANT	1288.5	1288.5		-459.4	676.5
COEFFICIENT	-.357	+.525			
SHEAR	1896.7	1983.7	SHEAR REVERSED	2080.1	1840.4
	1896.5	1985.0		2081.2	1842.4
	1899.9	1984.0		2081.0	1845.0
	1901.3	1984.7		2081.5	1842.3
SUM	7594.4	7937.4	SUM	8323.8	7370.1
AVERAGE	1898.6	1984.3	AVERAGE	2080.9	1842.5
DIFFERENCE	+182.3	-141.8		1898.6	1984.3
CONSTANT	1289.0	1289.0		182.3	-141.8
COEFFICIENT	+.141	-.110			
MOMENT	2031.5	1832.5	MOMENT REVERSED	1964.5	2003.6
	2029.9	1834.9		1965.4	2007.9
	2029.2	1832.8		1964.7	2006.0
	2029.6	1834.1		1964.3	2007.6
SUM	8120.2	7334.3	SUM	7858.9	8025.1
AVERAGE	2030.1	1833.6	AVERAGE	1964.7	2006.3
DIFFERENCE	-65.4	+172.7		2030.1	1833.6
CONSTANT	10.829	10.829		-65.4	172.7
COEFFICIENT	-6.039	+15.948			

RUN #5

BEGGS DEFORMETER

DATA SHEET

RECORDER PERRY
OBSERVER LARSON

POINT # 4 PI
MICROSCOPE # 109 AL

SHEET # 32
DATE 16 MAY

PLUG	HORIZONTAL	VERTICAL
NORMAL	2129.8	2263.0
	2126.2	2262.5
	2130.0	2261.2
	2129.8	2265.3
SUM	8515.8	9052.0
AVERAGE	2128.9	2263.0

PLUG	HORIZONTAL	VERTICAL	PLUG	HORIZONTAL	VERTICAL
THRUST	2132.7	1977.6	THRUST REVERSED	2122.5	2570.2
	2133.6	1976.0		2125.4	2568.7
	2132.1	1978.1		2123.7	2568.9
	2131.1	1981.1		2124.3	2571.3
SUM	8529.5	7912.8	SUM	8495.9	10279.1
AVERAGE	2132.4	1978.2	AVERAGE	2124.0	2569.8
DIFFERENCE	-8.4	+591.6		2132.4	1978.2
CONSTANT	1287.6	1287.6		-8.4	591.6
COEFFICIENT	-.007	+.459			
SHEAR	2132.0	2333.3	SHEAR REVERSED	2135.5	2213.3
	2135.4	2331.1		2134.8	2212.3
	2135.7	2332.2		2140.5	2215.3
	2133.6	2333.5		2139.4	2209.3
SUM	8536.7	9330.1	SUM	8550.2	8850.2
AVERAGE	2134.2	2332.5	AVERAGE	2137.6	2212.5
DIFFERENCE	+3.4	-120.0		2134.2	2332.5
CONSTANT	1293.6	1293.6		3.4	-120.0
COEFFICIENT	+.003	-.093			
MOMENT	2136.3	2192.2	MOMENT REVERSED	2139.1	2347.7
	2135.2	2191.0		2139.9	2344.4
	2139.1	2194.0		2144.4	2348.7
	2140.4	2196.6		2142.2	2346.6
SUM	8551.0	8773.8	SUM	8565.6	9387.4
AVERAGE	2137.8	2193.4	AVERAGE	2141.4	2346.8
DIFFERENCE	+3.6	+153.4		2137.8	2193.4
CONSTANT	10.858	10.858		3.6	153.4
COEFFICIENT	+.332	+14.128			

RUN #5
BEGGS DEFORMETER
DATA SHEET

RECORDER Perry
OBSERVER Larson

POINT # 2PI
MICROSCOPE # 104AL

SHEET # 33
DATE 16 MAY

PLUG	HORIZONTAL	VERTICAL
NORMAL	1874.4	1944.5
	1875.6	1939.9
	1876.8	1941.7
	1873.2	1940.6
SUM	7500.0	7766.7
AVERAGE	1875.0	1941.7

PLUG	HORIZONTAL	VERTICAL	PLUG	HORIZONTAL	VERTICAL
THRUST	1879.5	1772.1	THRUST REVERSED	1875.4	2110.5
	1880.2	1770.0		1879.8	2110.6
	1880.3	1770.9		1878.5	2113.3
	1880.2	1771.8		1878.4	2114.4
SUM	7520.2	7084.8	SUM	7512.1	8448.8
AVERAGE	1880.0	1771.2	AVERAGE	1878.0	2112.2
DIFFERENCE	-2.0	+341.0		1880.0	1771.2
CONSTANT	1287.6	1287.6		-2.0	341.0
COEFFICIENT	-.002	+.265			
SHEAR	1886.6	1954.0	SHEAR REVERSED	1878.4	1899.1
	1878.8	1956.6		1878.9	1898.8
	1884.8	1958.4		1878.5	1900.9
	1880.8	1958.8		1882.0	1898.8
SUM	7531.0	7828.0	SUM	7517.8	7597.6
AVERAGE	1882.7	1957.0	AVERAGE	1879.4	1899.4
DIFFERENCE	-3.3	-57.6		1882.7	1957.0
CONSTANT	1293.6	1293.6		-3.3	-57.6
COEFFICIENT	-.003	-.045			
MOMENT	1890.1	1885.1	MOMENT REVERSED	1888.5	1987.0
	1885.0	1882.6		1886.9	1984.1
	1882.0	1883.5		1886.1	1986.1
	1884.5	1884.3		1885.5	1986.8
SUM	7541.6	7535.5	SUM	7547.0	7944.0
AVERAGE	1885.4	1883.9	AVERAGE	1886.7	1986.0
DIFFERENCE	+1.3	+102.1		1885.4	1883.9
CONSTANT	10.858	10.858		1.3	102.1
COEFFICIENT	+.120	+9.403			

RUN #5

BEGGS DEFORMETER

DATA SHEET

RECORDER PERRY

OBSERVER LARSON

POINT # 10 PI

MICROSCOPE # 1C & AL

SHEET # 34

DATE 23 MAY

PLUG	HORIZONTAL	VERTICAL
NORMAL		
SUM		
AVERAGE		

PLUG	HORIZONTAL	VERTICAL	PLUG	HORIZONTAL	VERTICAL
THRUST			THRUST REVERSED		
SUM			SUM		
AVERAGE			AVERAGE		
DIFFERENCE					
CONSTANT					
COEFFICIENT					
SHEAR	1961.3		SHEAR REVERSED	2506.4	
(TO THE RIGHT OF THE CUT)	1957.8		(TO THE RIGHT OF THE CUT)	2505.9	
	1958.3			2502.5	
	1958.8			2502.5	
SUM	7836.2		SUM	10017.3	
AVERAGE	1959.1		AVERAGE	2504.3	
DIFFERENCE	+545.2			1959.1	
CONSTANT	1289.0			+545.2	
COEFFICIENT	+.423				
MOMENT			MOMENT REVERSED		
SUM			SUM		
AVERAGE			AVERAGE		
DIFFERENCE					
CONSTANT					
COEFFICIENT					

CHECK RUN
BEGGS DEFORMETER
DATA SHEET

RECORDER PERRY
OBSERVER LARSON

POINT # £S
MICROSCOPE # 107 AL

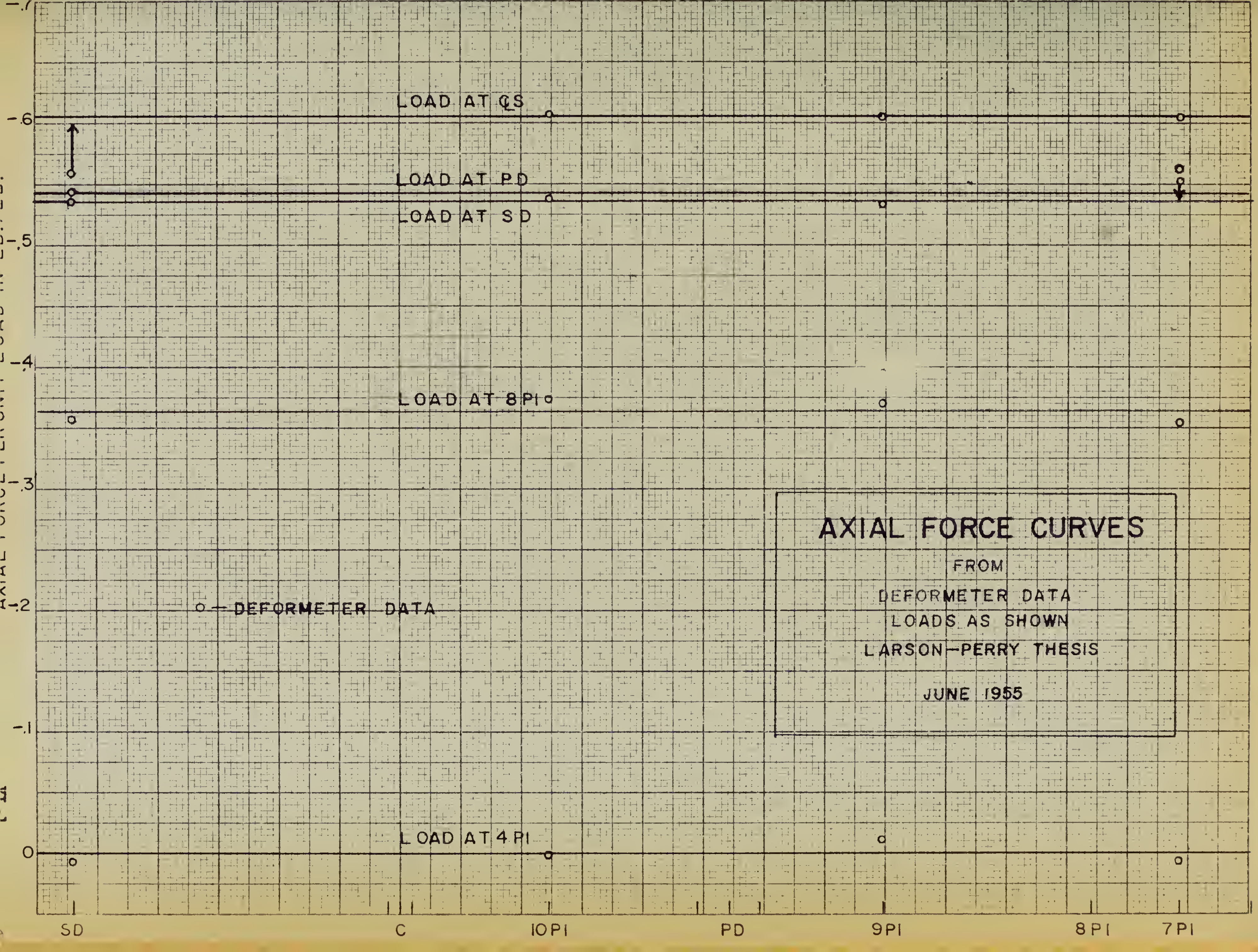
SHEET # 35
DATE 23 MAY

PLUG	HORIZONTAL	VERTICAL
NORMAL		
SUM		
AVERAGE		

PLUG	HORIZONTAL	VERTICAL	PLUG	HORIZONTAL	VERTICAL
~~THRUST~~	2311.1		THRUST	1681.0	
SHEAR	2311.5		REVERSED	1680.4	
9 PI	2311.1			1680.0	
CUT	2310.8			1681.4	
SUM	9244.5		SUM	6722.8	
AVERAGE	2311.1		AVERAGE	1680.7	
DIFFERENCE	-630.4			2311.1	
CONSTANT	1283.2			-630.4	
COEFFICIENT	-.491				
SHEAR	2267.4		SHEAR	1666.9	
10 PI	2270.3		REVERSED	1669.5	
Cut	2271.7			1669.3	
	2271.8			1667.8	
SUM	9081.2		SUM	6673.5	
AVERAGE	2270.3		AVERAGE	1668.4	
DIFFERENCE	-601.9			2270.3	
CONSTANT	1283.2			-601.9	
COEFFICIENT	-.469				
~~MOMENT~~	2233.5		MOMENT	1696.5	
SHEAR	2234.4		REVERSED	1694.4	
7 PI	2235.2			1695.1	
CUT	2233.2			1693.5	
SUM	8936.3		SUM	6779.5	
AVERAGE	2234.1		AVERAGE	1694.9	
DIFFERENCE	-539.2			2234.1	
CONSTANT	1283.2			-539.2	
COEFFICIENT	-.420				

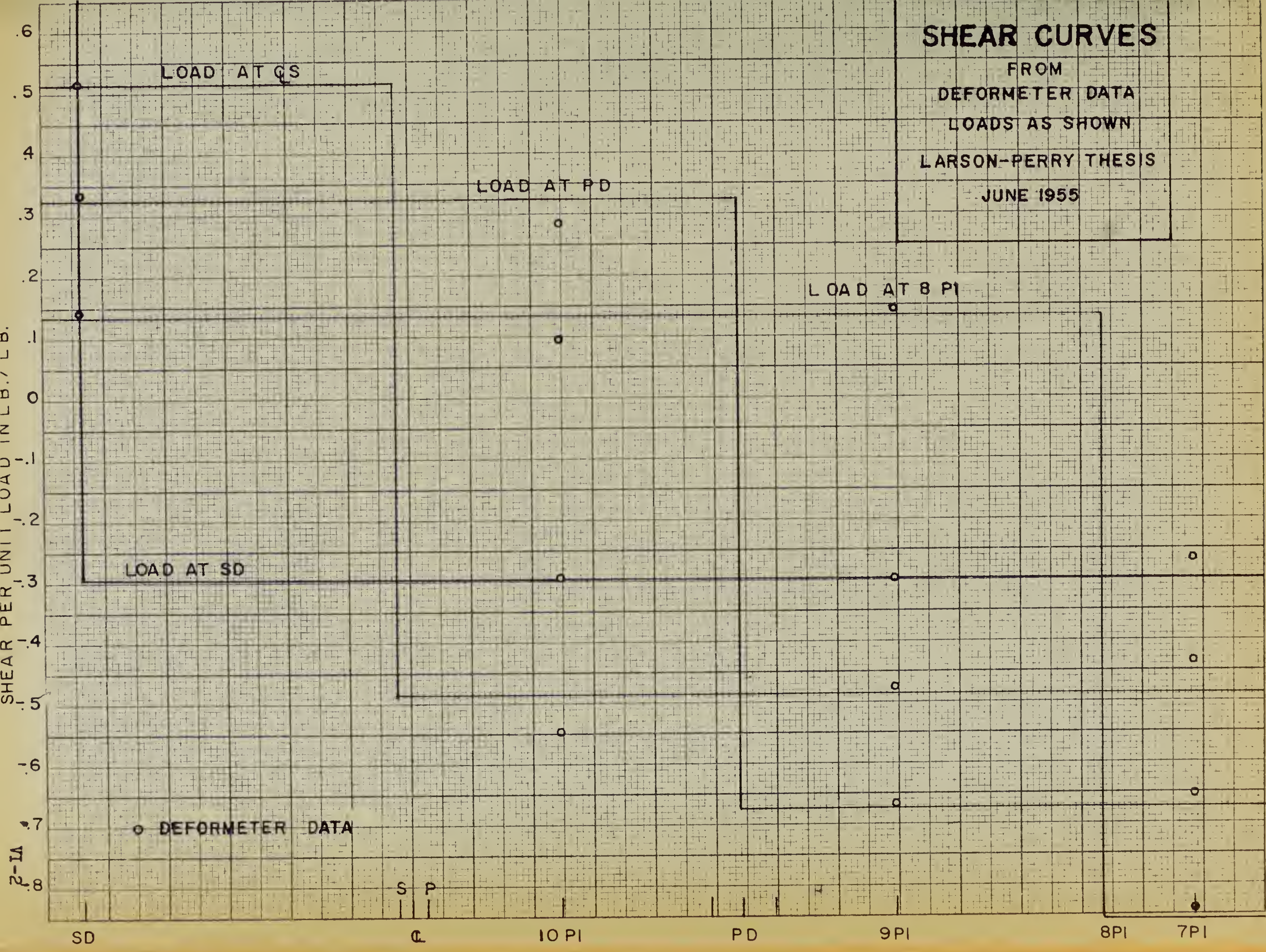
APPENDIX VI

# AXIAL FORCE, SHEAR, AND MOMENT CURVES
from
DEFORMETER READINGS



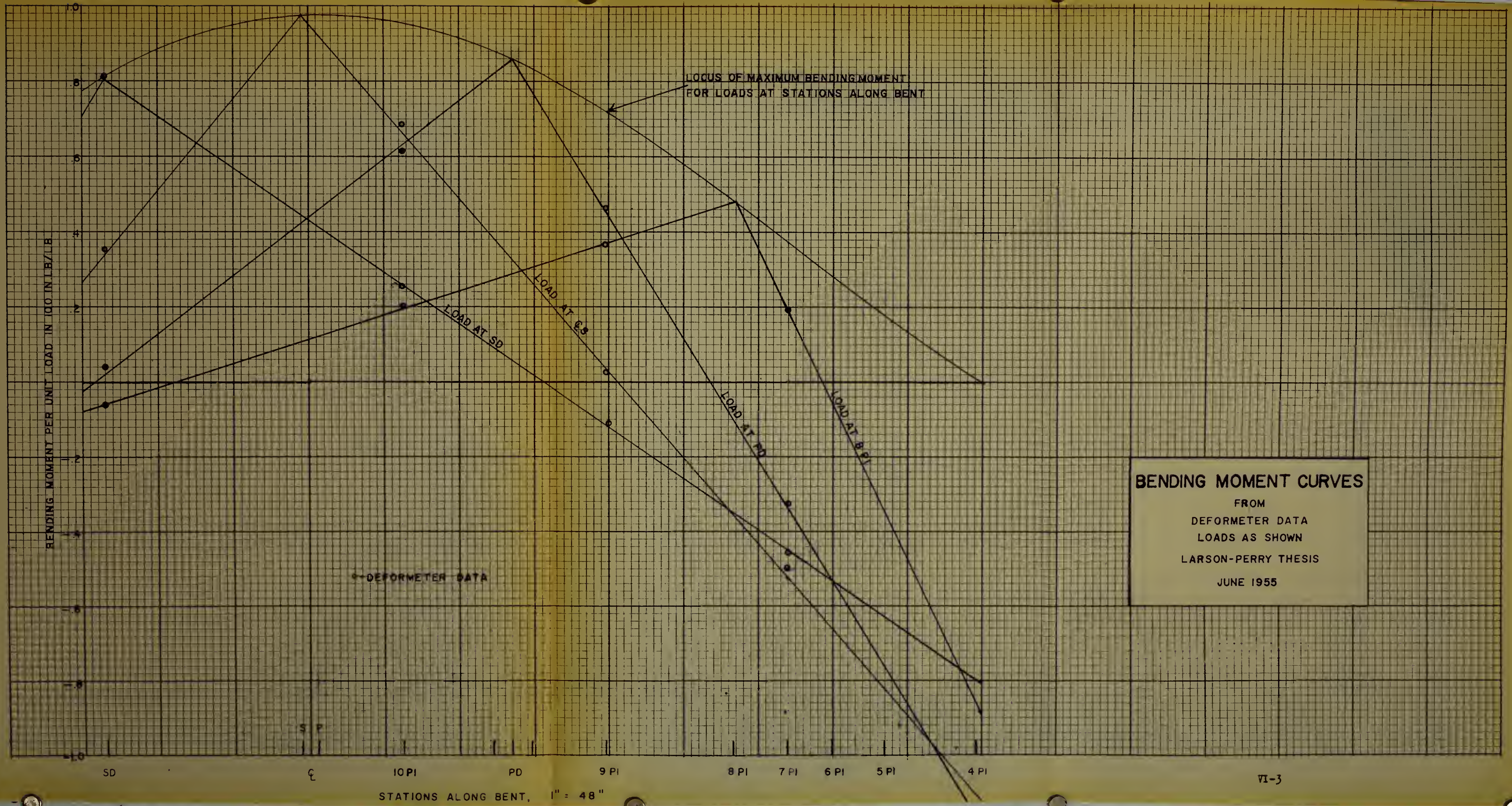
AXIAL FORCE CURVES
FROM
DEFORMETER DATA
LOADS AS SHOWN
LARSON—PERRY THESIS

JUNE 1955



SHEAR CURVES

FROM
DEFORMETER DATA
LOADS AS SHOWN
LARSON-PERRY THESIS
JUNE 1955



BENDING MOMENT CURVES

FROM

DEFORMETER DATA

LOADS AS SHOWN

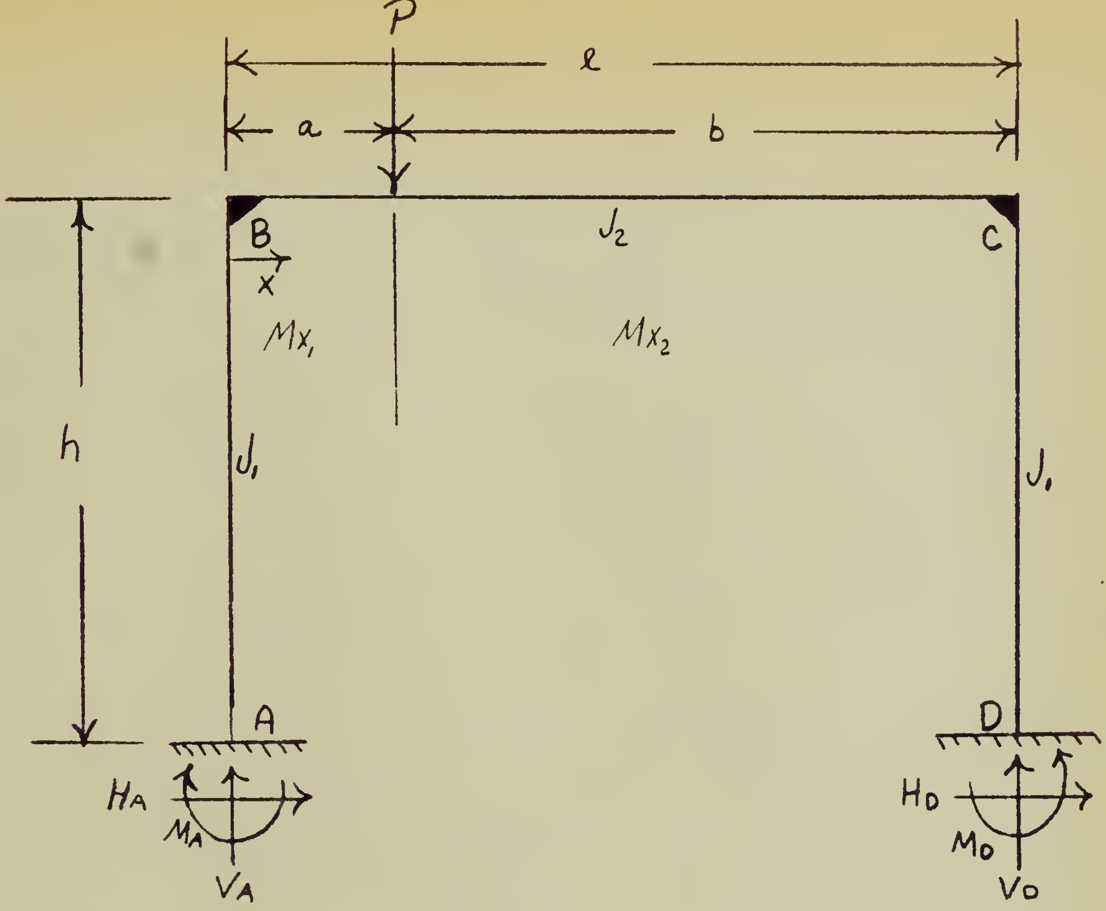
LARSON-PERRY THESIS

JUNE 1955

APPENDIX VII

THEORETICAL SOLUTION FOR INFLUENCE LINES

THEORETICAL SOLUTION FOR INFLUENCE LINES



CONSTANTS

$k = \frac{J_2}{J_1} \times \frac{h}{\ell}$

$N_1 = k + 2$

$N_2 = 6k + 1$

$\alpha = a/\ell$

$\beta = b/\ell$

$$M_A = M_D = +\frac{Pab}{\ell}\left[\frac{1}{2N_1} \mp \frac{\beta - \alpha}{2N_2}\right]$$

$$M_B = M_C = -\frac{Pab}{\ell}\left[\frac{1}{N_1} \pm \frac{\beta - \alpha}{2N_2}\right]$$

$$V_A = P\beta\left[1 + \frac{\alpha(\beta - \alpha)}{N_2}\right]$$

$$V_D = P - V_A$$

$$H_A = H_D = \frac{3Pab}{2\ell h N_1}$$

$$M_{x_1} = V_A\,x + M_B$$

$$M_{x_2} = V_D(\ell - x) + M_C$$

*Reference 27, Frame 41, pp 150-1

$C_{M_x} = M_x / P$ MOMENT INFLUENCE COEFFICIENT

$C V_x = V_x / P$ SHEAR INFLUENCE COEFFICIENT

$C_{H_x} = H_x / P$ AXIAL FORCE INFLUENCE COEFFICIENT

$$C_{V_{x_1}} = \beta\left[1 + \frac{(1-\beta)(2\beta-1)}{N_2}\right] = \beta\left[1 + \frac{R_1}{N_2}\right] = \beta R_2$$

$$C_{V_{x_2}} = C V_{x_1} - 1$$

$$C_{HX} = \frac{3ab}{2 \ell h N_1} = \frac{3\beta(1-\beta)}{2N_1} \cdot \frac{\ell}{h}$$

$$C_{MX_1} = X \times \beta \left[1 + \frac{\alpha(\beta-\alpha)}{N_2}\right] - \frac{ab}{\ell}\left[\frac{1}{N_1} + \frac{\beta-\alpha}{2N_2}\right]$$

$$= \beta x \left[1 + \frac{(1-3)(2\beta-1)}{N_2}\right] - \beta(1-\beta)\ell\left[\frac{1}{N_1} + \frac{(2\beta-1)}{2N_2}\right]$$

$$= x C V_{x_1} - B\ell$$

$$= \ell\left(\frac{x}{\ell} C V_{x_1} - B\right)$$

$$C_{Mx_2} = X - \beta x \left[1 + \frac{\alpha(\beta-\alpha)}{N_2}\right] - \frac{ab}{\ell}\left[\frac{1}{N_1} - \frac{\beta-\alpha}{2N_2}\right]$$

$$= X - \beta x \left[1 + \frac{(1-\beta)(2\beta-1)}{N_2}\right] - \beta(1-\beta)\ell\left[\frac{1}{N_1} - \frac{(2\beta-1)}{2N_2}\right]$$

$$= X - x C_{V_{x_1}} - B'\ell$$

$$= \ell\left[\frac{x}{\ell}\left(1 - C_{V_{x_1}}\right) - B'\right]$$

ASSUMED EQUIVALENT BENT

$J_1 = 66{,}631 \text{ IN}^4$

$J_2 = 46{,}180 \text{ IN}^4$

$h = 11.75 \times 24 \text{ IN}$

$\ell = 35.00 \times 24 \text{ IN} = 840 \text{ IN}$

$k = .233$

$N_1 = 2.233$

$N_2 = 2.396$

$P = 1^{\#}$

"SCALE" REFERS TO DISTANCE FROM ℄ IN GRAPH SCALE UNITS IN FIGURE 5

CALCULATION OF AXIAL FORCE AND SHEAR INFLUENCE COEFFICIENTS

β	$1-\beta$	2β	$2\beta-1$	R	R/N_2	$1+R/N_2$	C_{Vx1}	$C_{Vx}2$	$\beta(1-\beta)$	C_{Hx}	SCALE
0.0	1.0	0.0	-1.0	-1.00	-.4174	.5826	.0000	-1.0000	0.00	0.0000	180.0
0.1	0.9	0.2	-0.8	-0.72	-.3005	.6995	.0700	-0.9300	0.09	0.1801	144.3
0.2	0.8	0.4	-0.6	-0.48	-.2004	.7996	.1599	-0.8401	0.16	0.3201	107.2
0.3	0.7	0.6	-0.4	-0.28	-.1169	.8831	.2649	-0.7351	0.21	0.4202	71.5
0.4	0.6	0.8	-0.2	-0.12	-.0501	.9499	.3800	-0.6200	0.24	0.4802	35.7
0.5	0.5	1.0	0.0	0.00	.0000	1.0000	.5000	-0.5000	0.25	0.5002	0.0
0.6	0.4	1.2	0.2	0.08	.0334	1.0334	.6200	-0.3800	0.24	0.4802	-35.7
0.7	0.3	1.4	0.4	0.12	.0501	1.0501	.7351	-0.2649	0.21	0.4202	-71.5

CALCULATION OF B AND B' CONSTANTS

β	$1-\beta$	2β	$2\beta-1$	$\frac{2\beta-1}{2N_2}$	$\beta(1-\beta)$	( )	B	( )	B'	SCALE
0.0	1.0	0.0	-1.0	-.2086	0.00	.2392	.0000	.6564	.0000	180.0
0.1	0.9	0.2	-0.8	-.1669	0.09	.2809	.0253	.6147	.0553	144.3
0.2	0.8	0.4	-0.6	-.1252	0.16	.3226	.0516	.5730	.0917	107.2
0.3	0.7	0.6	-0.4	-.0835	0.21	.3643	.0765	.5313	.1116	71.5
0.4	0.6	0.8	-0.2	-.0417	0.24	.4061	.0975	.4895	.1175	35.7
0.5	0.5	1.0	0.0	.0000	0.25	.4478	.1119	.4478	.1119	0.0
0.6	0.4	1.2	0.2	.0417	0.24	.4895	.1175	.4061	.0975	-35.7
0.7	0.3	1.4	0.4	.0835	0.21	.5313	.1116	.3643	.0765	-71.5

x/1=.3489 (SD)

β	B	C_{Vx1}	$(x/1)C_{Vx1}$	(-B)	C_{Mx1}	SCALE
0.00	0.0000	.0000	0.0000	0.0000	000.0000	180.0
0.10	0.0253	.0700	0.0244	-.0009	- 0.756	144.3
0.20	0.0516	.1599	0.0558	0.0042	3.528	107.2
0.30	0.0765	.2649	0.0924	0.0159	13.356	71.5
0.40	0.0975	.3800	0.1326	0.0351	29.484	35.7
0.50	0.1119	.5000	0.1744	0.0625	52.500	0.0
0.60	0.1175	.6200	0.2163	0.1988	82.992	-35.7
0.70	0.1116	.7351	0.2565	0.1349	113.316	-71.5

x'/1= 1-x/1=.6511

β	B'	C_{Vx1}	K 1-CVx1	x'/1·K	( )	CMx2
0.00	0.0000	0.0000	1.0000	0.6511	0.6511	546.92
0.10	0.0553	0.0700	0.9300	0.6055	0.5502	462.17
0.20	0.0917	0.1599	0.8401	0.5470	0.4553	382.45
0.30	0.1116	0.2649	0.7351	0.4786	0.3670	308.28
0.40	0.1175	0.3800				
0.50	0.1119	0.5000				
0.60	0.0975	0.6200	0.3800	0.2474	0.1499	126.00
0.70	0.0765	0.7351	0.2649	0.1725	0.0960	80.64

x/1=0.5697

β	B	C_{Vx1}	(x/1)C_{Vx1}	(-B)	C_{Mx1}	SCALE
0.00	0.0000	.0000	0.0000	0.0000	0.0000	180.0
0.10	0.0253	.0700	0.0399	0.0146	12.264	144.3
0.20	0.0516	.1599	0.0911	0.0395	33.180	107.2
0.30	0.0765	.2649	0.1509	0.0744	62.496	71.5
0.40	0.0975	.3800	0.2165	0.1190	99.960	35.7
0.50	0.1119	.5000	0.2849	0.1730	145.32	0.0
0.60	0.1175	.6200	0.3532	0.2355	197.82	-35.7
0.70	0.1116	.7351	0.4188	0.3072	258.05	-71.5

x'/1=1-x/1=.4303

β	B'	C_{Vx1}	K 1-CVx1	x'/1·K	( )	CMx2
0.00	0.0000	0.0000	1.0000	0.4303	0.4303	361.45
0.10	0.0553	0.0700	0.9300	0.4002	0.3449	289.72
0.20	0.0917	0.1599	0.8401	0.3615	0.2698	226.63
0.30	0.1116	0.2649	0.7351	0.3163	0.2047	171.95
0.40	0.1175	0.3800	0.6200	0.2668	0.1493	125.40
0.50	0.1119	0.5000	0.5000	0.2152	0.1033	86.77
0.60	0.0975	0.6200	0.3800	0.1635	0.0660	55.44
0.70	0.0765	0.7351	0.2649	0.1140	0.0375	31.50

$x/1=0.7222$

β	B	C_{Vx1}	$(x/1)C_{Vx1}$	(-B)	C_{Mx1}	SCALE
0.00	0.0000	.0000	0.0000	0.0000	0.0000	180.0
0.10	0.0253	.0700	0.0506	0.0253	21.252	144.3
0.20	0.0516	.1599	0.1155	0.0639	53.676	107.2
0.30	0.0765	.2649	0.1913	0.1148	96.432	71.5
0.40	0.0975	.3800	0.2744	0.1769	148.596	35.7
0.50	0.1119	.5000	0.3611	0.2492	209.328	0.0
0.60	0.1175	.6200	0.4478	0.3303	277.452	-35.7
0.70	0.1116	.7351	0.5309	0.4193	352.212	-71.5

$x'/1=1-x/1=0.2278$

β	B'	C_{Vx1}	K 1-CVx1	x'/1·K	( )	CMx2
0.00	0.0000	0.0000	1.0000	0.2778	0.2278	233.52
0.10	0.0553	0.0700	0.9300	0.2584	0.2031	170.60
0.20	0.0917	0.1599	0.8401	0.2334	0.1417	119.03
0.30	0.1116	0.2649	0.7351	0.2042	0.0926	77.78
0.40	0.1175	0.3800	0.6200	0.1722	0.0547	45.95
0.50	0.1119	0.5000	0.5000	0.1389	0.0270	22.68
0.60	0.0975	0.6200	0.3800	0.1056	0.0081	6.80
0.70	0.0765	0.7351	0.2649	0.0736	-0.0029	-2.44

x/1=.8593 (7PI)

β	B	C_{Vx1}	(x/1)C_{Vx1}	(-B)	C_{Mx1}	SCALE
0.00	0.0000	.0000	.0000	.0000	0.0000	180.0
0.10	0.0253	.0700	.0602	.0349	29.3160	144.3
0.20	0.0516	.1599	.1374	.0858	72.072	107.2
0.30	0.0765	.2649	.2276	.1511	126.924	71.5
0.40	0.0975	.3800	.3265	.2290	192.36	35.7
0.50	0.1119	.5000	.4297	.3178	266.95	0.0
0.60	0.1175	.6200	.5328	.4153	347.34	- 35.7
0.70	0.1116	.7351	.6316	.5200	436.8	- 71.5

x'/1=1-x/1=.1407

β	B'	1-C_{Vx1}	K x'/1CVx1	x'/1-K	( )	CMX2
0.00	0.0000	0.0000	0.0000	0.1407	0.1407	118.19
0.10	0.0553	0.0700	0.0098	0.1309	00.0756	63.50
0.20	0.0917	0.1599	0.0225	0.1182	0.0265	22.26
0.30	0.1116	0.2649	0.0373	0.1034	-0.0082	- 6.89
0.40	0.1175	0.3800	0.0535	0.0872	-.0303	- 25.45
0.50	0.1119	0.5000	0.0704	0.0703	-0.0416	- 34.94
0.60	0.0975	0.6200	0.0872	0.0535	-0.0440	- 36.96
0.70	0.0765	0.7351	0.1034	0.0373	-0.0392	- 32.93

APPENDIX VIII

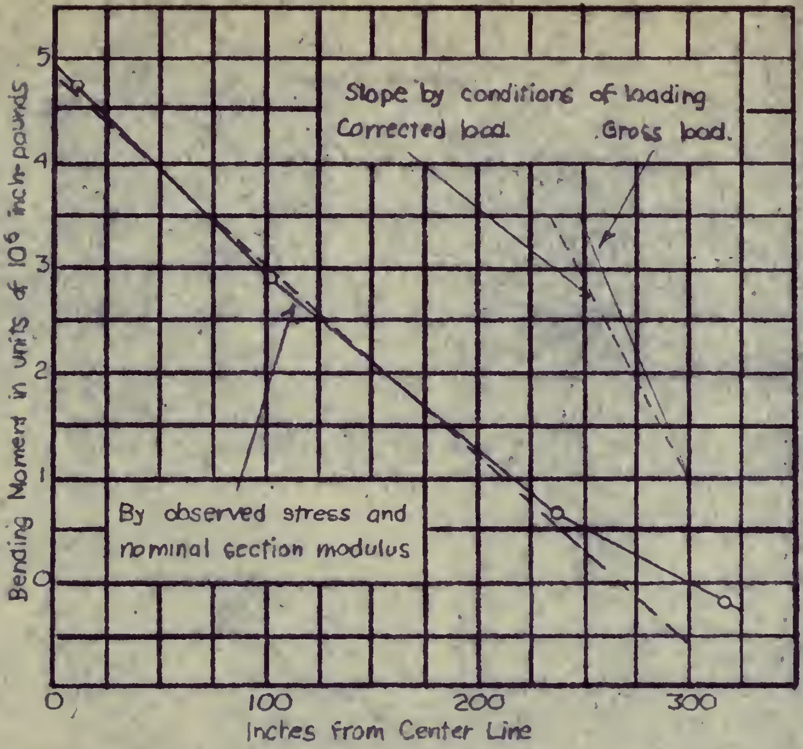
LISTING OF FULL-SCALE TEST DATA

USS YORKTOWN - Stresses in Bent Frames at Increasing Distances from

Main Deck - Bowstring Mode

Expressed in pounds per square inch per 100-kip load

Station	Fr. 155 Load Centerline	Fr. 155 Load Port
2PI	- 180	0
3PI	- 440	0
4PI	-2550	-3070
5PI	-2670	-3500
6PI	-3060	-3900
7PI	-3110	-3530
8PI	-1330	+ 340
9PI	- 680	+1590
10PI	+2430	+2100
CLP	+3320	+ 730
CLS	+4030	+ 600



USS YORKTOWN - Bending Moment in Beam, Frame 155, Centerline Load

USS YORKTOWN - Bending Moment, Frame 155, Off-Center Load

Units of 10^6 inch-pounds

Gage	M Calculated	M Observed
CLS	2.07	1.3
CLP	2.57	1.4
10PI	4.19	1.9
9PI	4.33	2.1
8PI	1.25	1.1
1PI	1.05	1.0

APPENDIX IX

CALCULATIONS OF STRESS VALUES

100 kip Load C_L (Theoretical)

POINT	Z (in.^{3})	A (in.^{2})	M	$Mx10^5/Z$	F	$Fx10^5/A$	STRESS
SD	877.45	41.61	53.0	6040.2	-0.500	-1201.6	4,838.6
CLS	1106.49	47.96	113.1	10221.5	-0.500	-1042.5	9,189.0
CLP	1106.49	47.96	113.5	10257.7	-0.500	-1042.5	9,215.2
10PI	1106.49	47.96	86.4	7808.5	-0.500	-1042.5	6,766.0
9PI	877.45	41.61	22.8	2598.4	-0.500	-1201.6	1,396.8
8PI	1297.88	49.78	- 18.0	-1386.9	-0.500	-1004.4	-2,391,3
7PI	1576.66	62.92	- 34.9	-2213.5	-0.500	- 794.7	-3,008.2
6PI	1955.46	76.42	- 49.0	-2505.8	-0.500	- 654.3	-3,160.1
5PI	2415.20	92.61	- 65.4	-2707.9	-0.500	- 540.0	-3,247.9
4PI	2389.50	91.54	- 95.3	-3988.3	-0.500	- 546.2	-4,534.5

STRESS = $Mx10^5/Z + Fx10^5/A$ for a 100 kip load

100kip Load C_L (Deformeter)

POINT	Z (in.^{3})	A (in.^{2})	M	$Mx10^5/Z$	F	$Fx10^5/A$	STRESS
SD	877.45	41.61	32.2	3669.7	-0.605	-1454.0	2215.7
CLS	1106.49	47.96	95.0	8585.7	-0.605	-1261.5	7324.2
CLP	1106.49	47.96	95.5	8630.9	-0.605	-1261.5	7369.4
10PI	1106.49	47.96	68.0	6145.6	-0.605	-1261.5	4884.1
9PI	877.45	41.61	4.7	535.6	-0.605	-1454.0	- 918.4
8PI	1297.88	49.78	- 37.8	-2912.4	-0.605	-1215.3	-4127.7
7PI	1576.66	62.92	- 52.5	-3329.8	-0.605	- 961.5	-4291.3
6PI	1955.46	76.42	- 66.3	-3390.5	-0.605	- 791.7	-4182.2
5PI	2415.20	92.61	- 82.8	-3428.3	-0.605	- 653.3	-4081.6
4PI	2389.50	91.54	-113.0	-4729.0	-0.605	- 660.9	-5389.9

STRESS = $Mx10^5/Z + Fx10^5/A$ for a 100 kip load

MOMENT CALCULATION FROM STRESS FOR 100 kip Load C_L (Actual)

POINT	Z (in.^{3})	A (in.^{2})	M	$Mx10^5/Z$	Deform F	$Fx10^5/A$	STRESS
SD	877.45	41.61					
CLS	1106.49	47.96	58.55	5291.5	-0.605	-1261.5	4030
CLP	1106.49	47.96	50.69	4581.5	-0.605	-1261.5	3320
10PI	1106.49	47.96	40.35	3691.5	-0.605	-1261.5	2430
9PI	877.45	41.61	6.79	774.0	-0.605	-1454.0	- 680
8PI	1297.88	49.78	- 1.49	- 114.7	-0.605	-1215.3	-1330
7PI	1576.66	62.92	-33.87	-2148.5	-0.605	- 961.5	-3110
6PI	1955.46	76.42	-44.36	-2268.3	-0.605	- 791.7	-3060
5PI	2415.20	92.61	-48.71	-2016.7	-0.605	- 653.3	-2670
4PI	2389.50	91.54	-45.14	-1889.1	-0.605	- 660.9	-2550

STRESS = $Mx10^5/Z + Fx10^5/A$ for a 100 kip load

100 kip Load Port (Theroetical)

POINT	Z (in.^{3})	A (in.^{2})	M	Mx10^5/Z	F	Fx10^5/A	STRESS
SD	877.45	41.61	11.0	1,253.6	-0.400	- 961.3	292.3
CLS	1106.49	47.96	40.8	3,687.3	-0.400	- 834.0	2853.3
CLP	1106.49	47.96	42.6	3,850.0	-0.400	- 834.0	3016.0
10PI	1106.49	47.96	55.6	5,024.9	-0.400	- 834.0	4190.9
9PI	877.45	41.61	86.0	9,801.1	-0.400	- 961.3	8839.8
8PI	1297.88	49.78	24.0	1,849.2	-0.400	- 803.5	1045.7
7PI	1576.66	62.92	- 2.0	- 126.9	-0.400	- 635.7	- 862.6
6PI	1955.46	76.42	- 24.0	-1,227.3	-0.400	- 523.4	-1750.7
5PI	2415.20	92.61	- 49.0	-2,028.8	-0.400	- 431.9	-2460.7
4PI	2389.50	91.54	- 95.3	-3,988.3	-0.400	- 437.0	-4425.3

STRESS = Mx10^5/Z + Fx10^5/A for a 100 kip load

100 kip Load Port (Deformeter)

POINT	Z (in.^{3})	A (in.^{2})	M	Mx10^5/Z	F	Fx10^5/A	STRESS
SD	877.45	41.61	- 3.8	- 433.1	-0.480	-1153.6	-1586.7
CLS	1106.49	47.96	25.0	2259.4	-0.480	-1000.8	1258.0
CLP	1106.49	47.96	27.4	2476.3	-0.480	-1000.8	1475.5
10PI	1106.49	47.96	40.3	3642.1	-0.480	-1000.8	2641.3
9PI	877.45	41.61	72.0	8205.6	-0.480	-1153.6	7052.0
8PI	1297.88	49.78	10.0	770.5	-0.480	- 964.2	- 193.7
7PI	1576.66	62.92	- 14.8	- 938.7	-0.480	- 762.9	-1701.6
6PI	1955.46	76.42	- 36.4	-1861.5	-0.480	- 628.1	-2489.6
5PI	2415.20	92.61	- 61.2	-2534.0	-0.480	- 518.4	-3052.4
4PI	2389.50	91.54	-107.3	-4490.5	-0.480	- 524.4	-6014.9

STRESS = Mx10^5/Z + Fx10^5/A for a 100 kip load

MOMENT CALCULATION FROM STRESS FOR 100 kip Load Port (Actual)

POINT	Z (in.^{3})	A (in.^{2})	M	Mx10^5/Z	Deform F	Fx10^5/A	STRESS
SD	877.45	41.61					
CLS	1106.49	47.96	17.71	1600.8	-0.480	-1000.8	600
CLP	1106.49	47.96	19.15	1730.8	-0.480	-1000.8	730
10PI	1106.49	47.96	34.31	3100.8	-0.480	-1000.8	2100
9PI	877.45	41.61	24.07	2743.6	-0.480	-1153.6	1590
8PI	1297.88	49.78	16.93	1304.2	-0.480	- 964.2	340
7PI	1576.66	62.92	- 43.63	-2767.1	-0.480	- 762.9	-3530
6PI	1955.46	76.42	- 63.98	-3271.9	-0.480	- 628.1	-3900
5PI	2415.20	92.61	- 72.03	-2981.6	-0.480	- 518.4	-3500
4PI	2389.50	91.54	- 60.83	-2545.6	-0.480	- 524.4	-3070

STRESS = $Mx10^5/Z + Fx10^5/A$ for a 100 kip load

APPENDIX X

STRESS DIFFERENCE CURVE DATA

STRESS DIFFERENCE CURVE DATA - CENTERLINE LOAD

SCALE	THEORY	DEFORM	PROTO	TH-DEF	TH-PRO	DEF-PRO
-3.0	4330	1690	460	2640	3870	1230
0.0	9380	7510	3800	1870	5580	3710
2.0	5240	3250	1540	1990	3700	1710
4.0	1080	-1030	- 720	2110	1800	- 310
5.0	-1000	-3150	-1860	2150	860	-1290
5.5	-2040	-3990	-2420	1950	380	-1570
6.0	-2770	-4250	-2900	1450	130	-1350
6.5	-3110	-4280	-3100	1170	10	-1180
7.0	-3180	-4180	-3080	1000	- 100	-1100
7.5	-3200	-4050	-2750	850	- 450	-1300
8.0	-3440	-4190	-2600	750	- 840	-1590
9.0	-4650	-5420	-2560	770	-2090	-1860

STRESS DIFFERENCE CURVE DATA - PORT LOAD

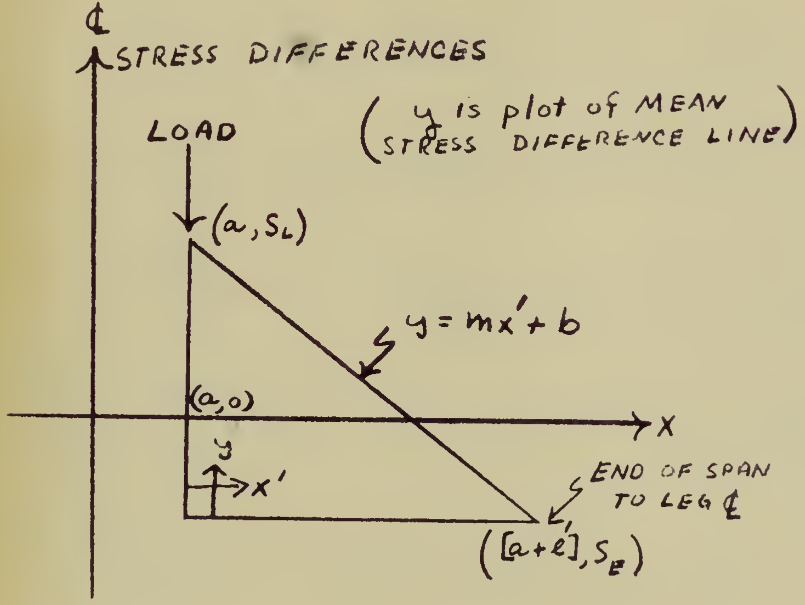
SCALE	THEORY	DEFORM	PROTO	TH-DEF	TH-PRO	DEF-PRO
-3.0	0	-1980	-1050	1980	1050	- 930
-2.0	950	- 800	- 500	1750	1450	- 300
-1.0	1930	300	60	1630	1870	240
0.0	2940	1350	650	1590	2290	700
1.0	4020	2400	1300	1620	2720	1100
2.0	5160	3520	1980	1640	3180	1540
3.0	6510	4820	2710	1690	3800	2110
3.5	7350	5660	3110	1690	4240	2550
4.0	8840	7050	3520	1790	5320	3530
4.5	5700	3950	2400	1750	3300	1550
5.0	3460	1890	1080	1570	2380	810
5.5	1600	340	- 530	1260	2130	870
6.0	150	- 870	-2450	1020	2600	1560
6.5	-1000	-1830	-3680	830	2680	1850
7.0	-1740	-2460	-3910	720	2170	1450
8.0	-2810	-3420	-3390	610	580	- 30
9.0	-4425	-6015	-3060	1590	-1365	-2955

APPENDIX XI

DERIVATION OF BENT DESIGN FORMULA

Development of Bent Formulae

1. Assume Stress Difference Curves and Actual Stress Curves plot as Straight Lines



$\ell' = \ell - a$

$x' = x - a$

$S_L = S_{CL} - S_{PL} = S_{CL}\left(1 - \frac{S_{PL}}{S_{CL}}\right)$

$S_E = S_{CE} - S_{PE} = S_{CE}\left(1 - \frac{S_{PE}}{S_{CE}}\right)$

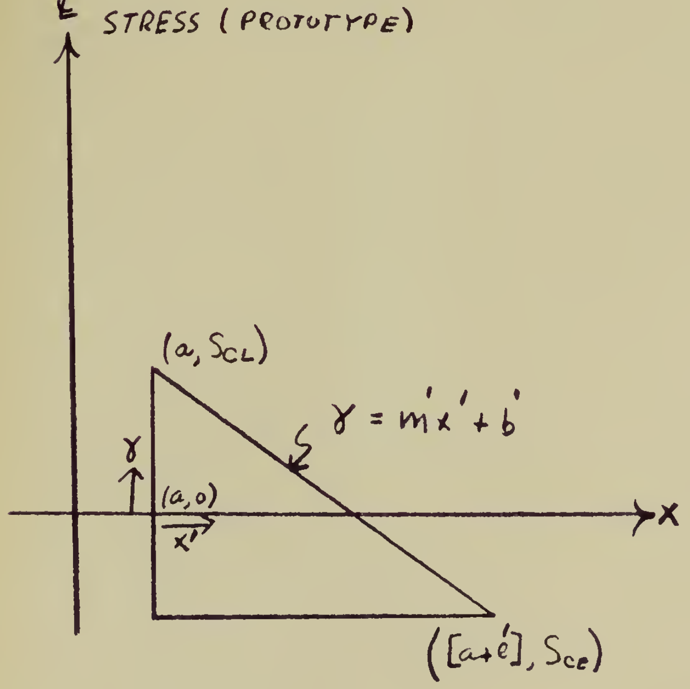
$x' = 0 \quad y = S_L - S_E$

$x' = \ell' \quad y = 0$

$b = S_L - S_E$

$m = -\frac{S_L - S_E}{\ell'}$

$y = (S_L - S_E)\left(1 - \frac{x'}{\ell'}\right)$



$\ell' = \ell - a$

$x' = x - a$

$x' = 0 \quad \gamma = S_{CL}$

$x' = \ell' \quad \gamma = S_{CE}$

$b' = S_{CL}$

$m' = \frac{S_{CE} - S_{CL}}{\ell'}$

$\gamma = (S_{CE} - S_{CL})\frac{x'}{\ell'} + S_{CL}$

For Any Point x

$$S_x = \gamma - (y + S_E)$$

$$S_x = (S_{CE} - S_{CL})\frac{x'}{\ell'} + S_{CL} - \left[(S_{CL})\left(1 - \frac{S_{PL}}{S_{CL}}\right) - (S_{CE})\left(1 - \frac{S_{PE}}{S_{CE}}\right)\right]\left(1 - \frac{x'}{\ell'}\right) - S_{CE}\left(1 - \frac{S_{PE}}{S_{CE}}\right)$$

$$S_x = S_{CE}\frac{x'}{\ell'} - S_{CL}\frac{x'}{\ell'} + S_{CL} - S_{CL} + S_{CL}K_1 + S_{CL}\frac{x'}{\ell'} - S_{CL}K_1\frac{x'}{\ell'} + S_{CE} - S_{CE}K_2$$

$$- S_{CE}\frac{x'}{\ell'} + S_{CE}K_2\frac{x'}{\ell'} - S_{CE} + S_{CE}K_2$$

$$S_x = \left(1 - \frac{x'}{\ell'}\right)\left(S_{CL}K_1 - S_{CE}K_2\right) + S_{CE}K_2$$

or

$$S_x = S_{CL}K_1 - \frac{x'}{\ell'}\left(S_{CL}K_1 - S_{CE}K_2\right)$$

or

$$S_x = S_{CL}K_1 - \frac{(x-a)}{(\ell-a)}\left(S_{CL}K_1 - S_{CE}K_2\right)$$

APPENDIX XII

CALCULATION OF CONSTANTS FOR BENT DESIGN FORMULA

CALCULATION OF BENT DESIGN FORMULA CONSTANTS

LOAD	DIRCT	$S_{cl} - S_{pl}$	S_{pl}	S_{cl}	$S_{ce} - S_{pe}$	S_{pe}	S_{ce}	K_1	K_2
CL-T	P&S	5570	3800	9370	-2710	-6080	-18790	.405	.692
CL-D	P&S	3710	3800	7510	-5010	-6080	-11090	.505	.548
P-T	P	4040	3190	7230	-3690	-8660	-12350	.441	.702
P-D	P	2590	3190	5780	-5650	-8660	-14310	.552	.605
P-T	S	4040	3190	7230	-1520	-4900	- 6420	.441	.764
P-D	S	2590	3190	5780	-3575	-4900	- 8475	.552	.578

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